IVGID - INCLINE RECREATION CENTER HVAC REPLACEMENT

SPECIFICATIONS

BID SET

February 14, 2025

AINSWORTH ASSOCIATES
MECHANICAL ENGINEERS

PROFESSIONAL ENGINEER - STATE OF NEVADA
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Exp. 06-30-25
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TABLE OF CONTENTS

SECTION 23 00 00 - HEATING, VENTILATING, AND AIR CONDITIONING

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. The Conditions of the Contract (General, Supplementary, and other Conditions) and the General Requirements (Sections of Division 1) are hereby made a part of this section.

B. This section lists general requirements for Heating, Ventilating, and Air Conditioning (HVAC) work and is hereby made a part of each Division 23 specification section.

C. For convenience or reference the Specifications are separated into Divisions and Sections. Such separations shall not operate to make the Engineer an arbitrator to establish subcontract limits between the Prime Contractor and his Subcontractors. In any case, the Prime Contractor is responsible to the owner for a complete job.

D. Wherever the word ‘provide’ is utilized with regard to materials or equipment on the drawings or in the specifications it shall be interpreted to mean ‘furnish and install’.

E. The term ‘exposed’ shall be interpreted to mean any equipment, ductwork, or piping that is not concealed above a continuous ceiling or inside a finished wall.

1.2 WORK INCLUDED

A. This section consists of general requirements and standard specifications covering certain parts of the HVAC work and is supplemented by other Division 23 specification sections covering additional work, requirements, and materials specifically applicable to the HVAC work of each section. Requirements of subsequent sections of the specifications, if in conflict with these general requirements, shall govern.

1.3 REQUIREMENTS OF REGULATORY AGENCIES

A. Provide work and materials in full accordance with the latest rules and regulations of the following:

Nevada

2018 International Building Code
2018 International Existing Building Code (when applicable)
2018 Uniform Mechanical Code
2018 Uniform Plumbing Code
2018 International Energy Conservation Code
2017 National Electrical Code
2018 International Fire Code
2018 NFPA Codes and Standards
Nevada State Fire Marshal
Nevada Occupational Safety and Health
National Fire Protection Association
Underwriters Laboratories
All other applicable state codes, rules, and regulations

B. Nothing in the drawings or specifications shall be construed to permit work not conforming to the listed codes and regulations.

C. In the event of an inconsistency between or within the plans, specifications, any of the contract documents, codes, or regulations, the better quality, higher cost, and/or greater quantity of materials and work shall be provided at no additional cost to the Owner.

1.4 FEES, PERMITS, AND UTILITY SERVICES

A. Obtain and pay for all permits and service required for installation of this work; arrange for required inspections and secure approvals from the authorities having jurisdiction.

B. Arrange for utility connections and coordinate work with utility company.

C. Arrange required inspections and secure approvals from the authorities having jurisdiction.

1.5 SITE EXAMINATION

A. Examine site, verify dimensions and locations against drawings, and inform self of conditions under which work is to be done before submitting proposal. No allowance will be made for extra expense on account of error.

B. Information shown relative to existing services is based upon available records and data but is approximate only. Make minor deviations found necessary to conform to actual locations and conditions without extra cost. Verify location and elevation of all utilities prior to commencement of excavation for new piping or its installation.

C. Exercise extreme care in excavating near existing utilities to avoid any damage thereto. This Contractor is responsible for any damage caused by his operations.

1.6 PLACEMENT OF EQUIPMENT AND WORK

A. The placement of equipment and mechanical work in the locations and spaces shown on the drawings is the Contractor’s responsibility.

B. Move equipment and/or work into spaces through openings provided or located in the spaces during construction, as required.

C. Perform disassembling and reassembling of equipment and/or other work necessary to accomplish this requirement without extra cost to the Owner.

1.7 SUBMITTALS AND SUBSTITUTIONS

A. In all cases, there is one basis of design manufacturer or product for each item of equipment or product shown on the drawings and/or specified herein. These products are identified by name and model number on the drawings and/or in the specifications. Alternative manufacturers and products are also listed; however, their inclusion as an alternative manufacturer or product does not cause them to be the basis of design. If an alternative manufacturer and/or product is desired to be used by the Contractor, it will be considered a substitution. Substitutions will be interpreted to be all manufacturers or products other than the basis of design. Only one request for substitution will be considered for each item of material or equipment. No substitutions will be considered thereafter. After a substitution request is reviewed and is found to be unacceptable the Architect/Engineer reserves the right to require the originally specified equipment or product at no additional cost to the Owner.

B. If the Contractor desires to make a substitution, he shall submit complete information or catalog data to show equality of equipment or material offered to that specified. No substitutions will be allowed unless requested and reviewed in writing. The Architect/Engineer will review and take appropriate action on shop drawings, product data, samples, and other submittals as required by the contract documents. Such review shall be only for general conformance with the design concept and general compliance with the information given in the contract documents.

C. The review of submittals will not include review of quantities, dimensions, weights or gauges, fabrication processes, construction methods, coordination with the work of other trades, or construction safety precautions, all of which are the sole responsibility of the Contractor. Review of a specific item shall not indicate acceptance of an assembly of which the item is a component. The Architect/Engineer shall not be required to review and shall not be responsible for any deviations from the Contract Documents not clearly noted by the Contractor, nor shall the Architect/Engineer be required to review partial submissions or those for which submissions for correlated items have not been received. The Architect/Engineer reserves the right to require the originally specified item.

D. Installation of reviewed substitutions is the Contractor's responsibility. Any changes required for installation of reviewed substituted equipment must be made without additional cost to the Owner. Review by the Architect/Engineer of the substituted equipment and/or the dimensioned drawings does not waive the requirements stated herein.

E. In any case where the Contractor intends to utilize a listed or unlisted acceptable equipment manufacturer that is not the basis of design as listed on the drawings and in the specifications it is the Contractor's responsibility to confirm prior to bidding that all ductwork, piping, controls, electrical power, conduit, service clearances, space requirements, and structural requirements match those of the basis of design equipment. Costs for any revisions necessary to accommodate the ductwork, piping, controls, electrical power, conduit, service clearances, space requirements, and structural requirements for the alternative equipment are the responsibility of the Contractor and shall be included in the Contractor's bid. No extra cost will be allowed for failure to allow for accommodations related to the alternative equipment in the Contractor's bid.

F. Submit to the Architect/Engineer for review, within a reasonable time after award of Contract and in ample time to avoid delay of construction, shop drawings or submittals on all items of equipment and materials, including all substitutions. Also see Division 1 for additional related requirements.

G. Partial or incomplete sets of equipment and materials submittals will not be acceptable.

H. Assessment of quantities is solely the Contractor's responsibility and will not be reviewed.

I. All submittal data shall be tailored to suit the specific project, with appropriate model or part numbers, materials, sizes, options, and accessories clearly indicated for each different submittal item and on each submittal page. Submittal pages without this information will be returned and will need to be resubmitted with all of the required information indicated on each sheet.

J. The Contractor shall certify that he has examined all submittal data and that the equipment and materials submitted for review meet or exceed the requirements of the drawings and specifications. Submittals without the required certification will not be acceptable.

K. Should the Contractor neglect to include submittal data for any item of equipment or material it shall be assumed and agreed that the associated equipment or material is the exact item specified as the basis of design on the drawings and in the specifications.

L. Items indicated by the Architect/Engineer to be resubmitted shall be resubmitted as follows:
   1. Retain items marked as 'No Exceptions Taken' or 'Make Corrections Noted' and resubmit with the revised package. Do not provide new sheets for these items.
   2. Provide revised submittal sheets for all other reviewed items. Provide originally submitted sheet with Architect/Engineer comments. Clearly indicate amendments and modifications made in response to previous submittal review comments.

M. Electronic Formatted Submittals
   1. Provide submittals in electronic form (.pdf file format).
   2. Identify and incorporate submitted information, including a cover sheet, and the following:
      a. Project Name
      b. Submittal Package Number (with revision number identified)
      c. Date
      d. Name of Architect/Engineer
      e. Name of Contractor
      f. Name of Subcontractor
   3. Group submitted items by specification section, and provide the following:
      a. Index of submitted products with page numbers
      b. Name of Firm or entity that prepared submittal
      c. Name of Supplier
      d. Name of Manufacturer
      e. Equipment and/or fixture tag, if applicable
      f. Number and title of appropriate specification section
   4. Items indicated by the Architect/Engineer to be resubmitted shall be resubmitted as follows:
      a. Retain items marked as ‘No Exceptions Taken’ or ‘Make Corrections Noted’ and resubmit with the revised package. Do not provide new sheets for these items.
      b. Provide revised submittal sheets for all other reviewed items.
      c. Provide originally submitted sheet with Architect/Engineer comments.
      d. Clearly indicate amendments and modifications made in response to previous submittal review comments.

PART 2 - PRODUCTS

2.1 MATERIALS AND EQUIPMENT

A. Mention herein or on the drawings requires that this Contractor provide each item listed of the quality noted, or equal. All material shall be new, full weight, standard in all respects, and in first class condition. Provide materials of the same brand or manufacturer throughout for each class of material or equipment wherever possible. Materials shall be tested within the continental United States by an independent, nationally recognized testing agency and shall be listed in accordance with testing agency requirements.

B. The grade or quality of materials desired is indicated by the trade names and/or catalog numbers stated on the drawings and in the specifications.

C. Dimensions, sizes, and capacities shown are a minimum and shall not be changed without the written permission of the Architect/Engineer.

D. All equipment shall comply with the mandatory equipment efficiencies listed in International Energy Conservation Code Section C403.3.2.

E. No material installed as part of this work shall contain asbestos in any form.

2.2 MATERIALS FURNISHED

A. Identify all materials and equipment by the manufacturer’s name and model number. Remove any unidentified materials and equipment from the site.

B. Equipment scheduled and/or specified by the manufacturer's model number shall include all accessories, controls, etc. listed in the catalog as standard with the equipment. Furnish optional or additional accessories as scheduled and/or specified.

C. Equipment or material damaged during transportation, installation, or operation is considered as totally damaged, and shall be replaced with new equipment. Variance from this requirement will be permitted only with the written consent of the Architect/Engineer.

D. Provide an authorized representative to constantly supervise the work of this division. Check all materials prior to installation for conformance with drawings and specifications.

PART 3 - EXECUTION

3.1 ACCESS TO HVAC WORK

A. Comply with manufacturer's written instructions for installation of access doors.

B. Access panels shall be furnished and installed wherever valves, balance valves, damper operating mechanisms, air terminal boxes, fans, and similar items normally requiring adjustment or servicing are installed in concealed or inaccessible spaces. Coordinate with access doors shown on architectural drawings.

C. Continuously check architectural drawings for clearance and accessibility of equipment specified herein to be placed. No allowance of any kind will be made for negligence on part of the Contractor to foresee means of installing his equipment into proper position.

3.2 DRAWINGS AND COORDINATION

A. General arrangement and location of piping, ductwork, equipment, etc. are shown on the drawings or herein specified. Carefully examine other work that may conflict with this work. Install this work in harmony with other crafts and at proper time to avoid delay of work.

B. In advance of construction, work out minor changes and relocations to suit actual conditions and work of other trades to avoid any conflicts. This shall not be cause for additional cost.

C. Verify all measurements at the building and be responsible for the correctness of same. No extra compensation will be allowed on account of differences between actual dimensions and those indicated on the drawings.

D. In addition, obtain all necessary information from the other trades regarding centers of partitions, walls, location of plumbing mains, fire sprinkler mains, and electrical conduits, ducts, pipes, etc. in order that pipes, equipment, and ductwork may be placed in their correct positions.

E. Execute all work shown on the drawings and not mentioned in the specifications, or vice versa, the same as if specifically mentioned by both. Omission from drawings or specifications of any minor details of construction, installation, materials, or essential specialties does not relieve the Contractor of furnishing and installing same in a complete and operational condition.

F. Furnish and install any incidental work not shown or specified which can reasonably be inferred as part of the work and necessary to provide a complete and operational system.

G. Furnish materials and work at proper time to avoid delay of the work.

3.3 AS-BUILT DRAWINGS

A. Upon completion of work submit to the Architect/Engineer as-built drawings showing all changes in equipment, piping, ductwork, etc. installed as part of this project which are not in accordance with the contract drawings. As-built drawing deliverables shall be in accordance with the requirements of Division 1, and shall consist of the following as a minimum.

1. Provide as-built drawings in electronic file format (pdf file). In addition to the electronic file, when field mark-ups have been utilized, provide a complete set of full size neatly and legibly marked as-built drawings on 20 pound white bond paper.
2. As-built drawings shall be full size (same size as the contract documents) and shall be standard engineering scale. The minimum drawing scale shall match those provided in the contract documents.
3. As-built drawings shall include all outside utility connections, piping, etc. installed under this Contract. Locate and dimension all work with reference to permanent landmarks.

B. Match all symbols and designations used in the contract drawings when preparing the as-built drawings.

C. Indicate clearly and correctly all work installed differently from that shown, and maintain records up to date as work progresses. Include invert elevations of pipes below grade of floor, the floor lines, plugged wyes, tees, caps, exact locations and sizing of piping, location of valves, and the like. Dimension locations from structural points.

D. Properly identify all stubs for future connections as to locations and use by setting of concrete markers at finished grade in manner suitable to the Architect/Engineer.

3.4 PROJECT MODIFICATIONS

A. During the progress of construction, if any conditions arise that necessitate revisions, modifications, or relocation of any mechanical equipment or materials, such revisions shall be immediately brought to the attention of the Architect/Engineer. The Contractor shall then prepare necessary drawings showing the proposed changes. All proposed changes shall be submitted, reviewed, and approved by the Architect/Engineer prior to proceeding with any associated revision work in the field.

B. Maintain copies of all approved changes at the project site for reference by all parties during the remaining work.

C. Incorporate all revisions into the as-built drawings.

3.5 CLOSING IN OF UNINSPECTED WORK

A. Do not allow or cause work installed to be covered up or enclosed before it has been inspected and tested. Should work be enclosed or covered up before it has been inspected and tested, uncover work at own expense. After it has been inspected and tested, make repairs necessary to restore work of other contractors to condition in which it was found at time of cutting.

3.6 FORMING, CUTTING, AND PATCHING

A. Coordinate with other contractors as necessary to provide any special forming, recesses, chases, etc., and provide wood blocking, backing, and grounds as necessary for proper installation of mechanical work.

B. If this Contractor fails to coordinate with other contractors at proper time or fails to locate items properly, resulting in extra work, then this Contractor is responsible.

C. This Contractor is responsible for proper placement of pipe sleeves, hangers, inserts, and supports for work.

D. Cutting, patching, and repairing of existing (old) construction to permit installation of piping, etc. is responsibility of this Contractor. Repair or replace damage to existing work with skilled mechanics for each trade involved in a first class manner.

3.7 EXISTING SERVICES

A. Provide and install all required connections to existing systems as required by the drawings and specifications.

B. Integrate existing systems with all new work to provide a complete working system.

C. Provide minimum 7 day notice to Owner of any service interruptions. All service interruptions shall be kept to the minimum possible time. When requested by Owner service interruptions shall occur outside of normal working hours.

D. The Contractor shall be responsible for damage to any part of the premises during the guarantee period that is caused by defects, leaks, or breaks in work furnished and/or installed under this section.

E. The Contractor shall replace refrigerant, lubricants, and/or gases lost as a result of defects, breaks, or leaks in the work.

F. The Contractor shall maintain continuous ADA accessibility, full path of travel and egress, and uninterrupted use of the existing elevator at all times.

3.8 PROJECT COMPLETION TESTS AND STARTUP

A. Upon completion of the mechanical work, or at such time prior to completion as may be determined by the Architect/Engineer, operate and test all mechanical equipment and systems for a period of at least five consecutive 8 hour days to demonstrate the satisfactory overall operation of the building or project as a complete unit. Include operation of heating and air conditioning equipment and systems for a period of not less than two 8 hour days at not less than 90 percent of full specified heating and cooling capacities in tests.

B. Commence tests after preliminary balancing and adjustments to equipment have been checked. Immediately before starting tests, install air filters and lubricate all running equipment. The Contractor shall notify the Architect/Engineer at least seven calendar days in advance of starting the tests listed herein.

C. Commence preliminary balancing and adjustments to equipment after all air ducts have been cleaned. The contractor must confirm that any dust or debris left over from the installation process has been removed. See specification section 23 31 00 3.3 for additional requirements.

D. Provide training and orientation of the Owner’s facilities staff in proper care and operation of equipment, systems, and controls.

E. Neatly tabulate and deliver to the Architect/Engineer complete operational data, including air flows, room temperatures, fan speeds, motor currents, plenum and duct static pressures, and other data as required. The Architect/Engineer reserves the right to spot check results, and if discrepancies or errors are noted, the Contractor will be required to redo balancing tests and tabulations entirely.

F. During the test period, make final adjustments and balancing of equipment, systems, controls, and circuits so that all are placed in a first class operating condition.

G. Mark final positions of balancing valves after balancing is complete.

H. All areas of the building shall receive proper flow of hot and chilled water to assure adequate and uniform temperatures throughout.

I. Final observation will not be conducted until all of the above requirements have been completed and the balance report has been submitted and reviewed.

3.9 TEMPORARY UTILITIES, HEATING, AND COOLING

A. Temporary utilities may be connected to the Owner's existing metered utilities only with the Owner's and the utility company's written authorization. Any connection to the Owner's existing utilities shall be separately metered to allow for proper allocation of utility costs unless another arrangement is specifically agreed to and authorized by the Owner in writing. Temporary meters shall be removed upon completion of the Work.

B. The Contractor shall be solely responsible for providing temporary heating, cooling, and/or ventilation as required to prevent degradation or damage to the Work. The permanent heating, cooling, and air handling systems shall not be utilized for the purpose of temporary heating, cooling, or ventilation until the Owner approves of such use in writing. In no case shall the permanent heating, cooling, or air handling systems be operated until they are complete, including formal startup, check out, and testing and balancing.

C. Utilization of any of the permanent heating, cooling, or air handling systems prior to the date of Substantial Completion shall not impact the specified warranty for such equipment, which shall begin on the date of Substantial Completion.

3.10 POST CONTRACT COMPLETION TESTS

A. If the required full load operation conditions cannot be conducted at the time of the 'Project Completion Tests and Startup' due to outdoor seasonal temperatures, the Contractor shall return to the job site when appropriate weather conditions arise (and/or when requested by the Architect/Engineer) to complete proper loading of equipment and systems as required. The Contractor will be allowed seven calendar days after notification to begin the tests. The Owner will be responsible for providing new air filters for the Contractor to install prior to this testing if necessary.

3.11 PRE-SEASON START UP

A. Within one year of filing of the Notice of Substantial Completion, when all full load tests required under 'Project Completion Tests and Startup' and 'Post Contract Completion Tests' have not yet been performed, the Contractor shall perform startup of any equipment or systems required for heating or cooling season operation when such equipment and systems have remained shut down or remain to be tested under full load. The Contractor shall ensure that all equipment and systems are operating properly before being turned over for the first operational use by the Owner. All such testing shall occur within one year of filing the Notice of Substantial Completion. The Owner will be responsible for providing new air filters for the Contractor to install prior to this testing if necessary.

3.12 GUARANTEE

A. The Contractor shall be responsible for all work done and material installed under the plans and specifications. Repair or replace, as may be necessary, any defective work, material, or part which may show itself within one year of filing of the Notice of Substantial Completion and be responsible for damage to other materials, furnishing, equipment, or premises caused by such defects during this period, if in the opinion of the Architect/Engineer said defect is due to imperfection of material or workmanship. Provide all such work and materials at no cost to the Owner.

3.13 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like, and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 05 00 - BASIC MATERIALS AND METHODS FOR HVAC

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. The Conditions of the Contract (General, Supplementary, and other Conditions) and Section 230000 (Heating, Ventilating, and Air Conditioning) are hereby made a part of this section.

B. This section provides requirements for basic materials and methods related to all of the HVAC work. This section applies to all other Division 23 specification sections.

1.2 WORK INCLUDED

A. Types of HVAC items specified in this section include the following:

1. Materials
2. Valves
3. Hangers and Supports for HVAC Systems
4. Seismic Bracing for HVAC Systems
5. Roof and Wall Flashings
6. Cathodic Protection
7. Pressure Gauges
8. Thermometers
9. Unions and Flanges
10. Pipe Escutcheons
11. Pipe Sleeves
12. Low Pressure Strainers
13. Penetrations in Fire and Smoke Rated Partitions and Floors
14. Pipe Anchors and Guides
15. Piping and Equipment Identification
16. Painting
17. Concrete Work
18. Electric Motors
19. Electric Motor Starters
20. Welding

1.3 PROJECT CONDITIONS

A. Existing Utilities: Locate and protect existing utilities and other underground work in manner which will ensure that no damage or service interruption will result from excavating and backfilling.

1.4 QUALITY ASSURANCE

A. Manufacturer's Qualifications: Firms regularly engaged in the manufacture of valves and piping specialties of types and sizes required, whose products have been in satisfactory use in similar service for not less than 5 years.

B. Valve Types: Provide valves of same type by the same manufacturer.

C. Identification: Provide valves and piping specialties with the manufacturer's name or trademark and pressure rating clearly marked on the valve body.

1.5 SUBMITTALS

A. Submit manufacturer's technical product data and installation instructions for each type of manufactured valve and piping specialty. Include pressure drop curve or chart for each type and size of isolation valve, balancing valve, and control valve.

B. Operation and Maintenance Data: Submit operation and maintenance data and spare parts lists for each type of manufactured valve and piping specialty. Include this data and product data in the operating and maintenance manual in accordance with all associated requirements.

C. All interface requirements (BACnet or other) shall be coordinated with the temperature control system subcontractor prior to issuing submittals and/or ordering any equipment that is required to have an interface.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Provide factory-fabricated valves and piping specialties as recommended by the manufacturer for use in the service indicated. Provide valves and piping specialties of types and with pressure ratings indicated for each service, or if not indicated, provide proper selections as determined by the Contractor to comply with the installation requirements. Provide sizes and connections which properly mate with pipe, tube, and equipment connections.

2.2 VALVES

A. See Specification Section 230510 (Valves for HVAC Systems).

2.3 HANGERS AND SUPPORTS FOR HVAC SYSTEMS

A. See Specification Section 230530 (Hangers and Supports for HVAC Systems).

2.4 SEISMIC BRACING FOR HVAC SYSTEMS

A. See Specification Section 230540 (Seismic Bracing for HVAC Systems).

2.5 ROOF AND WALL FLASHINGS

A. Flashing for penetrations of the roof for mechanical items such as ducts, pipes, and flues shall be as indicated on the drawings and in these specifications. Where exterior sheet metal flashings are indicated on the drawings or details, the flashings shall be galvanized sheet metal. The work of this section shall include layout, sizing, and coordination of roof and wall penetrations with all trades. Flues shall have a 24 gauge galvanized sheet metal storm collar securely clamped to the flue above the flashing.

2.6 CATHODIC PROTECTION

A. Furnish and install dielectric unions at all locations described herein, whether shown on drawings or not. Construct couplings and flanges so that the two pipes being connected are completely insulated from each other with no metal-to-metal contact. Couplings shall be lined with a hard, insulating, phenolic plastic threaded in standard pipe sizes.

B. Available Manufacturers: Subject to compliance with requirements, manufacturers which may be incorporated in the work include the following:

Nibco
Legend
Zurn
Watts

2.7 PRESSURE GAUGES

A. Pressure gauges shall be flangeless case type, Miljoco Model P4598L, or approved equal by Weiss or Weksler. Gauges shall be accurate to within plus or minus 1% throughout the entire scale range. Scales shall have a minimum of 2 degrees between graduations and a maximum of 20 degrees between figures.

B. Pressure gauges shall be 4-1/2 inch diameter with acrylic lens, stainless steel case, and stainless steel ring. Gauge movement shall be brass with precision-milled teeth. Gauges shall be selected with a pressure range such that the gauge reads near the middle of the total gauge range at the pressure indicated on the drawings. The most common gauge selections will be for ranges of 0 to 160, 0 to 60, and/or 0 to 30 psi.

2.8 THERMOMETERS

A. Thermometers shall be of the bimetal helix type, Miljoco Model B5098A, or approved equal by Weiss or Weksler. Thermometers shall be accurate to within plus or minus 1% throughout the entire scale range. Scales shall have a minimum of 2 degrees between graduations and a maximum of 20 degrees between figures.

B. Thermometers shall be 5 inch diameter with polycarbonate lens, stainless steel case and ring, stainless steel stem, and stainless steel well. Thermometer stem length for piping shall be 2-1/2 inches, and stem length for tanks shall be 9 inches. Thermometers installed on insulated tanks or piping shall be provided with an extension neck well to compensate for the thickness of the insulation.

C. Thermometer ranges shall be as listed below.

Location	Range
Chilled water supply and return mains.	25° to 125°F
Heating water supply and return mains.	0° to 250°F
Heat pump well field supply and return mains at each header.	25° to 125°F

D. Thermometers used for air temperature in ductwork, plenums, etc., shall have a perforated guard over the stem suitable for sensing air temperature. Stem length shall be 9 inches minimum.

E. Thermometers shall include an adjustable bracket allowing rotation to any position, and shall be located such that they are easily read from a normal vantage point.

F. Thermometer wells with chain and cap shall be provided as spares wherever spare wells are indicated on the drawings.

2.9 UNIONS AND FLANGES

A. Furnish and install unions at each threaded or soldered connection to all equipment, tanks and valves, of type specified in following schedule:

Type of Pipe	Union
Steel pipe 2" and smaller	150 lb threaded malleable ground joint, brass to iron seat, black for black piping, galvanized for galvanized piping.
Steel pipe 2-1/2" and larger	125 lb cast iron threaded flanged union, flat faced, gasket, black for black piping, galvanized for galvanized piping.
Copper tubing 2" and smaller	150 lb bronze ground joint, bronze to bronze sweat connection.
Copper tubing 2-1/2" and larger	150 lb cast bronze, flat faced flange with silver brazing threadless ends.

B. Insulating couplings or flanges shall be furnished and installed at all connections of piping with dissimilar materials. Construct couplings so that the two pipes being connected are completely insulated from each other with no metal-to-metal contact. Heavily line the couplings with a hard, insulating, phenolic threaded coupling in standard pipe sizes.

C. Furnish and install flanges at each flanged connection to equipment, tanks, and valves per the following schedule:

Type of Pipe	Flanges
Threaded black or galvanized steel pipe 2-1/2" and larger	125 lb threaded cast iron, flat face flange, black or galvanized steel as applicable.
Welded steel pipe 2-1/2" and larger	150 lb welded forged steel, raised face flange.

D. Provide full faced or ring type gasket material to suit facing on flanges. Gasket material shall be 1/16" thick Garlock Blue-Gard, or approved equal. Gasket material shall be suitable for the connected piping system content and temperature.

2.10 PIPE ESCUTCHEONS

A. Provide chrome plated brass pipe escutcheons with inside diameter closely fitting pipe outside diameter or outside of pipe insulation where pipe is insulated. Select outside diameter of escutcheon to completely cover pipe penetration hole in floors, walls, ceilings, or pipe sleeve extension, if any. Furnish pipe escutcheons with nickel or chrome finish and screw or spring clamping device with concealed hinge.

B. Available Manufacturers: Subject to compliance with requirements, manufacturers offering pipe escutcheons which may be incorporated in the work include the following, or approved equal:

Chicago Specialty Manufacturing Company
Producers Specialty and Manufacturing Corporation
Sanitary Dash Manufacturing Company

2.11 PIPE SLEEVES

A. Where pipes pass through a concrete floor slab the pipe shall be covered with high density fiberglass insulation. Pipe insulation shall be 1/2” to 1” thick Johns Manville Microlok HP or Johns Manville Trymer 25-50 for the full thickness of the concrete. After the piping has been installed and the concrete has been poured, the fiberglass insulation shall be cut away or compressed leaving a 1/2” deep space that shall then be filled with a high quality silicone sealant resulting in a flat, water-tight installation.

B. Where pipes pass through fire rated concrete floors or walls install a Schedule 10 galvanized metal sleeve providing between a 1/2 inch and 1 inch clearance around the sides of the pipe and/or pipe insulation for the full thickness of the concrete. After the piping has been installed, fill the annular space in accordance with the applicable UL fire rating system.

C. Available Manufacturers: Subject to compliance with requirements, manufacturers offering pipe sleeves which may be incorporated in the work include the following, or approved equal:

3M

2.12 LOW PRESSURE STRAINERS

A. Provide wye or basket strainers as indicated on the drawings. Strainers shall be full line size of connecting piping, with ends matching the piping system materials, and with cast iron body. Select strainers for 125 psi working pressure, with stainless steel screens, and gasket seal. Provide hose end ball valve on drain fitting.

B. Strainer screens shall have an open area equal to at least twice the cross-sectional area of the pipe in which they are installed (based on IPS) and may be either woven wire or perforated type. Strainer openings shall be .045 inch diameter perforations for strainers up to 3” size and .125 inch diameter perforations for strainers 4” size and larger.

C. Available Manufacturers: Subject to compliance with requirements, manufacturers offering low pressure strainers which may be incorporated in the work include the following, or approved equal:

Metraflex

Taco
Bell & Gossett
Watts

2.13 PENETRATIONS IN FIRE AND SMOKE RATED PARTITIONS AND FLOORS

A. Maintain indicated fire or smoke rating of walls, partitions, ceilings, and floors at pipe, conduit, and duct penetrations. Seal all penetrations with fire-stop and smoke-stop materials complying with the requirements for firestopping and fill materials specified in this section.

B. Schedule and conduct a firestopping pre-installation conference at the job site. Coordinate all firestopping means and methods with other contractors and the general contractor (when applicable) prior to beginning any work.

C. Installer Qualifications: A firm that has been approved by FM Global according to FM Global 4991 (Approval of Firestop Contractors), or been evaluated by UL and found to comply with their ‘Qualified Firestop Contractor Program Requirements’.

D. Install all penetration firestopping systems to comply with the manufacturer's written installation instructions and published drawings for products and applications.

E. Do not install penetration firestopping system when ambient or substrate temperatures are outside limits permitted by the penetration firestopping system manufacturer or when substrates are wet because of rain, frost, condensation, or other causes.

F. Install and cure penetration firestopping materials per manufacturer's written instructions using natural means of ventilation, or where this is inadequate, forced-air circulation.

G. The specified firestopping systems are based on a solid sealant only, or combinations of solid sealant, foam sealant, and refractory fibers of thickness required to attain hour ratings.

H. Fire and Smoke Partition Systems shall comply with the following:
   1. Provide a flexible seal to prevent passage of fire, smoke, toxic gases, and water through openings, and prevent transmission of sound and vibration from the penetrating element to the structure.
   2. Provide hour ratings indicated and in accordance with ASTM E814 and/or UL 1479.
   3. For projects located in the State of California comply with requirements of CBC Sections 709.6, 709.7, 709.8, 710.2, 710.3 and 710.6, and CBC Standards 7-1 and 7-5.

I. Acceptable Manufacturers: 3M, Hilti, SpecSeal, Nelson, HoldRite, Tremco, Roxtec, or approved equal. The established standard in most cases is 3M, unless otherwise specified. The listed products are specified to establish standards and the type of materials required. Materials shall be as specified, or approved equal.

J. Sealant: Select among the following materials as appropriate.
   1. Solid (Elastomeric): 3M Fire Barrier Premium Latex CP 25WB+ Caulk, one-component elastomeric water-based latex sealant designed for use as a through-penetration firestop
   2. Foam: 3M Fire Barrier 2001 Silicone RTV Foam, two-component silicone elastomer foam-in-place sealant designed to fill irregular or complex voids.
   3. Wrap Strip: 3M Fire Barrier FS-195+ Wrap Strip, fire resistive strip designed to be wrapped around the penetrating item and secured in place.
   4. Restricting Collar: 3M Fire Barrier RC-1 Restricting Collar, sheet metal, designed for use with wrap strip in combustible through-wall firestop penetration systems.
   5. Composite Sheet: 3M Fire Barrier CS-195+ Composite Sheet, elastomeric layer reinforced with mesh restraining wire and covered with aluminum foil on one side and bonded to sheet metal, forming a fire resistive sheet.
   6. Putty: 3M Fire Barrier MP Moldable Putty+ Pads and Sticks, one-component elastomeric formable putty, designed for use as a through-penetration firestop system.
   7. Spray: 3M FireDam Spray 100, flexible water-based coating.
   8. Primers: As recommended by the sealant manufacturer.

K. Pillows: Nelson PLW Firestop Pillow, Hilti FS Fire Block, dust proof chemical resistant cloth with heat-reactive expanding solidifying fill, designed for large openings that require frequent cable alterations.

L. Safing Insulation: USG Thermafiber Safing Insulation, 4 lb density mineral wool insulation, unless indicated otherwise.

M. Damming Materials: As recommended by the firestopping manufacturer.

2.14 PIPE ANCHORS AND GUIDES

A. Provide pipe anchors and guides as indicated on the drawings and/or as required to accommodate any thermal expansion, contraction, or seismic movement of the piping system. Pipe anchors and guides shall be Metraflex Model PGIV, or approved equal by Mason Industries.

2.15 PIPING AND EQUIPMENT IDENTIFICATION

A. Each piping system furnished and installed under this work shall be identified and the direction of flow indicated by means of colored labels and flow arrows, all as specified herein. The labels shall be applied after all painting, priming, and cleaning of the piping and insulation is completed.

B. Provide prefabricated coiled plastic piping labels as manufactured by Marking Services Incorporated (MSI), or approved equal. Labels shall comply with ASME A13.1 with regard to color, letter height, and marker size. The labels shall have black or white lettering and flow arrows on colored backgrounds and shall not require adhesive. The background colors shall conform to the color schedule included in the ‘Execution’ section of this specification.
   1. For pipe labels used indoors use coiled polyester labels, MSI Model MS-975, or equal.
   2. For pipe labels used outdoors use coiled polyester labels, MSI Model MS-995, or equal.
   3. For piping with an outside diameter, including insulation, greater than 6 inches provide the label manufacturer’s nylon straps to secure label to piping. Labels shall lie smoothly against pipe or insulation completely around the pipe.
   4. The size of the lettering and label shall be such that the lettering can be easily read from the floor and the colors shall be easily discernible.

C. Provide a white plastic lamacoid plate for each and every piece of equipment installed in this work. Lettering on plate shall be black, with size of lettering to suit equipment. Lettering shall be a minimum of 1/2 inch in height. Plates shall be riveted or bolted to equipment near electrical disconnect or control access panel.

D. Where mechanical or plumbing equipment requiring access is located above a ceiling or behind an access panel, provide an adhesive clear plastic label with 3/8” black lettering on the ceiling grid or access panel identifying the equipment.

E. Ground loop circuit piping inside a mechanical room shall be labeled to coincide with the numbering indicated on the mechanical drawings.

F. Available Manufacturers: Subject to compliance with requirements, manufacturers which may be incorporated in the work include the following, or approved equal:

Marking Services Incorporated (MSI)
LEM Products
Seton
Craftmark

2.16 PAINTING

A. In general, painting will be done by others. Exposed piping and unfinished portions of equipment to be painted shall be cleaned by this Contractor of grease, oil, rust, or dirt in preparation for painting. Spot prime all factory primed surfaces as necessary.

2.17 CONCRETE WORK

A. Where specifically indicated on the drawings or specified as part of the mechanical work, this Contractor shall furnish and install concrete work such as thrust blocks and/or spring isolator bases.

B. Concrete and reinforcing steel shall be equal to that specified for general construction.

C. Except as noted above, concrete work will be furnished and installed by others. This Contractor shall coordinate all requirements accordingly.

2.18 ELECTRIC MOTORS

A. Electric motors larger than 1/2 horsepower rating, unless otherwise noted, shall be ball bearing, open drip proof, squirrel cage, induction type, normal starting torque, 3 phase, 60 cycle service, 40°C continuous rating, and shall conform in all respects to latest applicable standards of NEMA and AIEE. Motors shall be Century, Louis Allis, Baldor, or equal. Motors located outdoors shall be TEFC type.

B. All motors 1 horsepower and above shall be premium efficiency type, Century E-Plus, or approved equal.

C. Motors utilized with variable frequency drives shall be rated as inverter duty per NEMA standards.

D. Motors shall have nameplate voltage rating of operating voltage specified in subsequent sections of specifications or as shown on drawings and shall have a 1.15 service factor.

E. For normal applications, motors shall be furnished for normal starting torque duty. It shall be this Contractor's responsibility, however, to provide motors and starters (where starters are furnished under this section) having suitable starting torque and current characteristics to allow starting the equipment within the branch circuit protection provided and within the overload protection required by code.

F. Splash-proof or totally enclosed motors having a continuous duty temperature rise rating not exceeding 35°C shall have adequate starting torque, as recommended by the manufacturer, for the service intended.

G. All motors shall be rated at ±10% of the scheduled voltage. If not, provide each motor with a boost transformer sized for the intended use and installed in a rated enclosure.
   1. Boost transformers for equipment provided under the mechanical work shall be furnished by the mechanical contractor and turned over to the electrical contractor for installation, unless otherwise noted.

H. Shaft Grounding
   1. All variable frequency drive motors less than 300 horsepower shall have a single shaft grounding system to protect the bearings from capacitive discharge through the bearings.
   2. Available Manufacturers: Subject to compliance with requirements, manufacturers which may be incorporated in the work include the following, or approved equal:

      CR Series by Shaft Grounding Systems
      AEGIS SGR Conductive Microfiber Brush

2.19 ELECTRIC MOTOR STARTERS

A. Magnetic motor starters for equipment provided under the mechanical work shall be furnished by the mechanical contractor and turned over to the electrical contractor for installation, unless otherwise noted. All motor starters shall be by the same manufacturer, Westinghouse, Square D, Cutler-Hammer, General Electric, or approved equal.

B. Magnetic motor starters provided as part of motor control centers shall be provided and installed by the electrical contractor.

C. Unless otherwise noted, magnetic motor starters shall be furnished in a NEMA 1 enclosure for inside installation and in a gasketed NEMA 4 enclosure for outside installation, with three thermal overloads for three phase motors and one overload element for single phase motors. All overloads shall be ambient compensated.

D. Submit schedule to the Architect/Engineer denoting the following:
   1. Designation of each motor
   2. Name plate rating of each motor
   3. Running current of each motor
   4. Catalog number and rating of starter overload elements
   5. Circuit breaker trip size (when in combination starter)

E. Combination magnetic starters shall be Westinghouse Type A206 with circuit breaker disconnect and trip size of breaker as required for motor size, or as otherwise noted.

F. Magnetic motor starters shall be Westinghouse Type A200, or approved equal.

G. Manual motor starters shall be Westinghouse Type MST01 less enclosure, or approved equal.

H. Magnetic motor starters shall be provided with cover-mounted Hand-Off-Auto ‘Oil-Tight’ type switches as scheduled, with integral fused 120 volt control transformer.

2.20 WELDING

A. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

B. Steel Support Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M (Structural Welding Code - Steel).

C. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code Section IX. Comply with ASME B31.9 (Building Services Piping) for materials, products, and installation.

PART 3 - EXECUTION

3.1 INSTALLATION OF PIPING SPECIALTIES

A. Pipe Escutcheons: Install pipe escutcheons on each pipe penetration through floors, walls, partitions, and ceilings where penetration is exposed to view and on exterior of building. Secure escutcheon to pipe or insulation so escutcheon covers penetration hole and is flush with adjoining surface.

B. Sleeves: Secure sleeves to metal or wood forms in such a manner that they will not become displaced during pouring of concrete. Fill sleeves on deck with sand. After forms have been removed from concrete, the sleeves shall be removed from the openings.

C. Core drill properly sized holes in the concrete to replace metal sleeves that are crushed or knocked out of position during pouring of concrete.

D. Provide piping passing through concrete fire walls with sleeves of standard black steel pipe nominally one size larger than pipe enclosed, but in the case of insulated pipe, large enough for insulation to pass through. Caulk space between pipe and sleeve with fire rated wicking, and provide metal retainer plates at both sides of the wall.

3.2 INSTALLATION OF LOW PRESSURE STRAINERS

A. Install low pressure strainers full size of connected piping in accordance with manufacturer's installation instructions. Install pipe nipple and shutoff valve in strainer blow down connection, full size of connection, except for strainers 2 inches and smaller installed ahead of control valves feeding individual terminals. Where indicated, provide drain line from shutoff valve to plumbing drain, full size of blow-down connection.

B. Locate strainers in the supply line ahead of the following equipment and elsewhere as appropriate, if an integral strainer is not included in the equipment:

Pumps
Temperature and/or flow control valves
Pressure reducing valves
Temperature and/or pressure regulating valves

3.3 INSTALLATION OF HANGERS AND SUPPORTS

A. See Specification Section 230530 (Hangers and Supports for HVAC Systems). Where special hanger/support of piping or ductwork is detailed or shown on the drawings, the drawings shall be followed.

3.4 INSTALLATION OF VALVES

A. Install valves where required for proper operation of piping and equipment, including valves in branch lines where necessary to isolate sections of piping. Locate valves so as to be accessible and so that separate support can be provided when necessary.

B. Install valves with stems pointed up, in vertical position where possible, but in no case with stems pointed downward from horizontal plane.

C. Provide union at each connection to equipment and downstream of each valve. Provide unions at both ends of valves when valves cannot be turned due to an obstruction.

D. After piping systems have been tested and put into service, but before final testing, adjusting, and balancing, inspect each valve for possible leaks. Adjust or replace packing to stop leaks; replace valve if leak persists.

E. Tag each valve and provide a complete listing of valve locations and functions. Valve and tag listing shall be laminated and turned over to the Owner for posting as desired. In addition, where valves are located above a ceiling or behind an access panel, provide an adhesive clear plastic label with black 3/8” lettering on ceiling grid or access panel identifying the valve.

3.5 INSTALLATION OF UNIONS AND FLANGES

A. Install unions and flanges so that piping can be easily disconnected for removal of tanks, equipment, and valves. Provide two unions at each 2-way valve and 3 unions at each 3-way valve.

3.6 INSTALLATION OF CATHODIC PROTECTION

A. Install dielectric unions in the following locations:
   1. At points in piping where dissimilar metal pipes are connected together.
   2. Any special applications shown on the drawings.

3.7 INSTALLATION OF GAUGES

A. Provide gauge connections at the following locations:
   1. Suction and discharge of chilled water, heating water, and geothermal bore field pumps.
   2. Inlet and outlet of butterfly type balancing valves.
   3. Elsewhere as shown on the drawings.

B. Gauges shall be provided in convenient locations within approximately 3 feet of the flanges or connections and elsewhere as may be shown on the drawings.

C. Gauge Valves and Siphons
   1. A needle point globe valve, Crane No. 88 or equal, shall be installed at each gauge.
   2. A gauge siphon shall be installed at each hot water gauge.

3.8 INSTALLATION OF THERMOMETERS

A. Thermometers for piping systems shall be installed so that the liquid flows completely around the sensing well. Pipe sizes at the bulb shall be increased where necessary to allow for full flow without excessive resistance.

B. Where shown on the temperature control diagrams, the temperature control subcontractor shall furnish and install remote panel-mounted thermometers. Duct-mounted thermometers may be omitted at these locations.

C. Thermometers shall be placed at all locations shown on the drawings.

D. In cases where the specified thermometers cannot be located so as to be easily read, a remote reading type thermometer shall be installed, as approved by the Architect/Engineer.

E. Thermometers provided as part of the temperature control work and located on a control panel need not be duplicated by the requirements listed above.

3.9 INSTALLATION OF PIPE IDENTIFICATION

A. Identification shall be applied to all piping, except piping located in furred spaces without access to permit entrance of personnel, and piping buried in the ground or concrete.

B. The legend and flow arrow shall be applied at all valve locations, at all points where piping enters or leaves a wall, partition, cluster of piping, or similar obstruction, and at approximately 20 foot intervals on pipe runs.

C. Practical variations or changes in locations and spacing may be made with the specific approval of the Architect/Engineer to meet specific conditions.

D. Wherever two or more pipes run parallel, the printed legend and other markings shall be applied in the same relative location so that all piping is easily identified.

E. Markings shall be located to be conspicuous from any reasonable vantage point.

F. The legends and flow arrows shall be in the colors as indicated in the pipe marking schedule.

G. Pipe labels shall be as described in Section 2.20 of this specification (Piping and Equipment Identification).

H. Pipe Marking Schedule

Service	Color
Heating Water Supply and Return	White on Green
Chilled Water Supply and Return	White on Blue
Heat Pump Supply and Return Water	White on Gray
Steam	Black on Yellow
Steam Condensate	White on Yellow

I. Where different equipment such as fire sprinklers are supplied from a common main, such as a domestic water main, the main should be identified as 'Domestic Water' and each respective branch takeoff as 'Fire Water', etc.

3.10 INSTALLATION OF AIR VENTS

A. Install air vents in hydronic systems at all high points and as required to adequately bleed all air from the piping systems and equipment during initial filling, normal operation, and subsequent filling of each piping system.

B. Install air vents in steam and condensate systems at all high points and as required to adequately bleed all air from the piping systems and equipment during initial filling, normal operation, and subsequent filling of each piping system. Air vents for steam systems shall be balanced pressure type, Spirax Sarco Model VS-204, or approved equal by Armstrong.

3.11 DEMOLITION WORK

A. Demolition work shall be performed only where specifically identified on the drawings. Unless specifically indicated otherwise, demolition work shall include removal of all associated equipment, electrical and controls components, conduit and wiring, piping, valves and accessories, and supports. The surfaces where the demolition work was performed shall be restored to match the adjacent surfaces to the best extent practical.

B. When demolition work involves leaving existing systems in place for a prolonged time period (more than 30 days and/or any time period when there is the potential for freezing temperatures) the Contractor shall protect all existing equipment, piping, and ductwork from potential damage during the time that the equipment, piping, and ductwork is out of service. The protection procedures shall include draining all hydronic coils and the associated piping systems that may be susceptible to freezing temperatures when the building heating system is disabled. This requirement applies to both hydronic piping and domestic water piping systems. After the piping systems are drained, the Contractor shall purge all water from the hydronic coils, hydronic piping systems, and domestic water piping systems using compressed air or other appropriate means, and shall seal any open ends such that the potential for corrosion is minimized. This work shall be performed by an experienced mechanical or plumbing contractor, rather than by a demolition contractor.

3.12 FORMING, CUTTING, AND PATCHING

A. Coordinate with other contractors as necessary to provide any special forming, recesses, chases, etc., and provide wood blocking, backing, and grounds as necessary for proper installation of mechanical work.

B. If this Contractor fails to coordinate with other contractors at the proper time or fails to locate items properly, resulting in extra work, the Contractor is responsible for the additional work, at no cost to the Owner.

C. This Contractor is responsible for proper placement of pipe sleeves, hangers, inserts, and supports for all work.

D. Cutting, patching, and repairing of existing (prior) construction to permit installation of piping, conduit, etc. is the responsibility of the Contractor. Repair or replace any damage that occurs to existing work in a first class manner using skilled mechanics for each trade involved.

E. Cut existing construction in a neat and workmanlike manner by the use of a concrete saw. Use of pneumatic devices is not acceptable.

F. Core openings through existing construction as required for the passage of any new piping and/or conduit. Cut holes of the minimum diameter required to suit the size of the pipe to be installed, including the associated insulation.

3.13 ELECTRICAL WORK

A. Adequate working space shall be provided around electrical equipment in compliance with the National Electrical Code and other applicable codes. Mechanical work shall be coordinated with the electrical work in order to comply with these requirements. Any work which does not conform to these requirements shall be corrected without additional cost to the Owner.

B. Furnish and install all line and low voltage temperature control wiring in the mechanical work (typically furnished and installed by the temperature control subcontractor) including all interlock wiring between motor starter coils, interlock relays, and temperature control equipment. Unless noted otherwise, this does not include primary control wiring between starters and pushbuttons, other manual starter switches, or branch power circuits required for the temperature control system.

C. Electrical Coordination

1. Starters located in motor control centers will be provided under the electrical work. The Contractor is referred to electrical drawings for motors served by motor control centers.
2. Motors furnished under the mechanical work shall be furnished by the mechanical contractor, but connection to power wiring shall be by the electrical contractor. Coordinate all motor starter requirements with the electrical contractor.
3. Temperature control equipment, including relays shown on control diagram, shall be furnished and installed by the temperature control subcontractor.
4. Electrical devices with piping connections, such as solenoid valves, insertion thermostats, strap-on aquastats, and similar items which are to be wired under the electrical work or by the temperature control subcontractor, shall be installed by the mechanical contractor.

D. Equipment furnished in this work that is factory wired but requires modification to internal wiring to meet specifications or drawing requirements shall have such internal modifications made at the factory before shipment.

E. All electrical work and equipment, including internal wiring, shall comply with applicable codes and applicable portions of the electrical specifications. Route line and low voltage control wiring in conduit. Conduit for temperature control wiring shall be the responsibility of the mechanical contractor and shall be of the type specified in Division 26.

3.14 POST-CONSTRUCTION OWNER TRAINING

A. In addition to the Owner training requirements listed in all other specification sections, the Contractor shall provide an overall comprehensive training session one month prior to the one year warranty expiration date. This session is intended to address any and all questions that the Owner’s facility staff may have with regard to operation and maintenance of all of the installed mechanical systems.

3.15 CARE AND CLEANING

A. Repair or replace broken, damaged, or otherwise defective parts, materials, and work. At completion, carefully clean and adjust equipment and trim installed as part of this work. Leave systems and equipment in a satisfactory operating condition.

3.16 OPERATION TEST

A. Test each piece of equipment to show that it will operate in accordance with the indicated requirements.

3.17 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like, and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 05 10 - VALVES FOR HVAC SYSTEMS

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. The Conditions of the Contract (General, Supplementary, and other Conditions) and Section 230000 (Heating, Ventilating, and Air Conditioning) are hereby made a part of this section.

1.2 WORK INCLUDED

A. Types of valves specified in this section include the following:

- Ball Valves
- Butterfly Valves
- Check Valves
- Manual Balance Valves
- Automatic Pressure-Compensating Flow Limiting Valves
- Air Vent Valves
- Tempering Valves
- Pressure Relief Valves

PART 2 - PRODUCTS

2.1 VALVES

A. Provide factory-fabricated valves as recommended by the manufacturer for use in the service indicated. Provide valves of types and with pressure ratings indicated for each service, or if not indicated, provide proper selection as determined by the Contractor to comply with the installation requirements. Provide sizes and connections which properly mate with pipe, tube, and equipment connections.

B. Unless otherwise indicated, valves shall be the same size as the upstream pipe size.

C. Provide valves as shown on drawings and other valves necessary to segregate branches and equipment.

D. Furnish discs suitable for the service intended. Furnish a brass tag for each valve identifying the applicable service. Properly pack and lubricate all valves per manufacturer's recommendations. Place a union adjacent to each threaded valve. Provide a union on both sides of soldered valves. Furnish the flow performance curve for each valve.

E. Provide flanged valves in welded pipe, provide ball valves in water lines, unless otherwise indicated on the drawings.

F. Valves shall be full size of pipe, manufactured by Nibco, Milwaukee, Apollo, or equal, in accordance with the following listing:

Ball Valves	2" and below	Nibco T-585-70-66	Milwaukee BA-400S
Butterfly Valves	2-1/2" and above	Nibco LD-2022	Milwaukee HL-234E
Check Valves	2" and below	Nibco T-453-B	Milwaukee 508
	2-1/2" and above	Nibco F-968-B	Milwaukee F-2970-M

G. Ball Valves: All ball valves shall have stainless steel ball and stem, PTFE packing, and throttling handle. Provide motor-operated ball valves where indicated on the drawings. Motor-operated ball valves shall be Belimo B2 Series, or approved equal.

H. Butterfly Valves: All butterfly valves shall be lug style ductile iron body, with EPDM seats, stainless steel disc and stem, and throttling handle with memory stop. Provide handles for shutoff service, and infinite position throttling capability, with indicator plates for balancing. Provide motor-operated butterfly valves where indicated on the drawings. Motor-operated butterfly valves shall be Belimo F6 Series, or approved equal.

I. Lockshield valves shall be lead-free ball type with locking lever, Nibco T-585-80-LF-LL, Crane D171LS, or approved equal.

J. Manual Balance Valves (2" and Below): Fixed port venturi style, Pro-Hydronic CBV Series, IMI Flow Design AccuSetter UA Series, Pro-Hydronic CBVF Series, Taco Accu-Flo, Bell & Gossett Circuit Setter Plus, Nibco T-1810, or approved equal. Variable orifice balancing valves are not acceptable.

K. Manual Balance Valves (2-1/2" and Above): Fixed port venturi style, Pro-Hydronic CBVF Series, IMI Flow Design AccuSetter AF Series, Hays Series CBVF, Nexus Series NVFB, Bell and Gossett Circuit Setter Plus, Nibco F739, or approved equal. Variable orifice balancing valves are not acceptable.

L. Automatic Pressure-Compensating Flow Limiting Valves: Valves shall be Pro-Hydronic Model AFLB, IMI Flow Design Model AC, Hays Mesurflo Model 2517, Nibco Model T-1880, or approved equal. Include removable stainless steel cartridge, union, and test ports. Field adjustable type valves shall be Bell & Gossett Ultra Setter, Oventrop Cocon QTZ, or approved equal.

M. Manual Air Vent Valves: Manual air vents shall be furnished as indicated on the drawings, complete with ball type isolation valve, Hoffman Model 78, or approved equal. Valve pressure rating shall be as required for the system in which installed.

N. Automatic Air Vent Valves: Automatic air vents shall be furnished as indicated on the drawings and shall be Hoffman No. 79, Spirotherm Spirotop, or approved equal. Pipe vents to the nearest floor sink. Valve pressure rating shall be as required for the system in which installed.

O. Pressure Relief Valves

1. Provide ASME rated pressure relief valves and temperature and pressure relief valves as indicated on the drawings. Valve size and capacity shall be as required for proper relieving capacity equal to or greater than the capacity of the associated equipment output rating. Valves shall be sized and rated for compliance with Section IV of the ASME Boiler and Pressure Vessel Code and ANSI Z21.22 where applicable.
2. Pressure Relief Valves: Where indicated on the drawings for boilers, heat exchangers, chillers, etc. provide bronze body relief valves with test lever, complying with listing requirements for temperature and pressure discharge capacity. Valves shall be Watts Series 174A, Series 374, Series 740, or approved equal.
3. Combined Pressure and Temperature Relief Valves: When indicated on the drawings for water heaters and/or hot water storage tanks provide bronze body relief valves with test lever and thermal sensor (thermostat), complying with listing requirements for temperature and pressure discharge capacity. Valves shall be Watts XL Series, or approved equal.
4. Available Manufacturers: Subject to compliance with requirements, manufacturers offering relief valves which may be incorporated in the Work include the following, or approved equal:

   Watts
   Bell and Gossett
   Spirax Sarco

PART 3 - EXECUTION

3.1 INSTALLATION OF VALVES

A. Install valves where required for proper operation of piping and equipment, including valves in branch lines where necessary to isolate sections of piping. Locate valves so as to be accessible and so that separate support can be provided when necessary.

B. Install valves with stems pointed up, in vertical position where possible, but in no case with stems pointed downward from horizontal plane.

C. Provide union at each connection to equipment and downstream of each valve. Provide unions at both ends of valves when valves cannot be turned due to an obstruction.

D. After piping systems have been tested and put into service, but before final testing, adjusting, and balancing, inspect each valve for possible leaks. Adjust or replace packing to stop leaks; replace valve if leak persists.

E. Tag each valve and provide a complete listing of valve locations and functions. Valve and tag listing shall be laminated and turned over to the Owner for posting as desired. In addition, where valves are located above a ceiling or behind an access panel, provide an adhesive clear plastic label with black 3/8” lettering on ceiling grid or access panel identifying the valve.

3.2 CARE AND CLEANING

A. Repair or replace broken, damaged, or otherwise defective parts, materials, and work. At completion, carefully clean and adjust equipment and trim installed as part of this work. Leave systems and equipment in a satisfactory operating condition.

3.3 OPERATION TEST

A. Test each piece of equipment to show that it will operate in accordance with the indicated requirements.

3.4 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like, and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 05 20 - OPERATION AND MAINTENANCE OF HVAC SYSTEMS

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

1.2 OPERATING AND MAINTENANCE INSTRUCTIONS

A. Furnish the Architect/Engineer with two complete sets of typewritten operating and maintenance instructions, descriptive literature, catalog cuts, and diagrams covering all items of operation and maintenance for each and every mechanical system and piece of equipment furnished under these specifications.

B. In addition to the bound hard copies the Contractor shall provide an electronic copy (pdf file).

C. The Contractor shall begin compiling the above data (including obtaining operating and maintenance instruction data, catalog cuts, and diagrams from the manufacturer of the reviewed equipment) immediately upon review of his list of materials, so as not to delay the final installation and acceptance of the work.

D. Bind and index each set in a durable, hardboard binder. Final observation should not be requested until the operating and maintenance binders are submitted and have been reviewed by the Architect/Engineer.

E. Incorporate complete operating instructions including starting, stopping, and description of emergency manual operation methods for the following:

1. Heating Systems
2. Ventilating Systems
3. Air Conditioning Systems
4. Piping Systems
5. Temperature Control Diagrams
6. Test Data and Startup Reports

F. Provide charts and diagrams as required.

G. Provide operating manual for all equipment listed in individual sections of the specification.

H. Provide maintenance instructions for each item of individual equipment covering pertinent maintenance data, such as lubricants to be used, frequency of lubrication, inspections required, adjustments required, etc.

I. Provide parts bulletins containing manufacturer's part numbers, instructions, etc. for each item of equipment. Strip bulletins so that useless bulk is avoided.

J. Post service telephone numbers and/or addresses in an appropriate place as designated by the Architect/Engineer or Owner.

END OF SECTION

SECTION 23 05 30 - HANGERS AND SUPPORTS FOR HVAC SYSTEMS

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Section 230000 (Heating, Ventilating, and Air Conditioning), Section 230500 (Basic Materials and Methods for HVAC), and Section 230540 (Seismic Bracing for HVAC Systems) are hereby made a part of this section.

1.2 GENERAL

A. The following information is for pipe hanger and support layout and design reference only. The actual design of all hangers, supports, and seismic bracing is the responsibility of the Contractor per the following specification sections:

Specification Section 23 05 30 (Hangers and Supports for HVAC Systems)
Specification Section 23 05 40 (Seismic Bracing for HVAC Systems)

B. Piping: Hangers and supports for piping shall be designed in accordance with the latest adopted edition of the standards and codes listed below, and with any other applicable standards. Except in cases where a pipe stress analysis is performed to justify adjusted support and restraint spacing, pipe hangers and supports shall not be placed at intervals that are further apart than the requirements listed in UPC Table 313.3 and in UMC Table 313.3.

Steel Piping	Maximum Spacing	Reference
1-1/4” and smaller	7 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
1-1/2”	9 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
2”	10 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
2-1/2”	11 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
3”	12 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
3-1/2”	13 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
4”	14 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
Copper Piping	**Maximum Spacing**	**Reference**
3/4” and smaller	5 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
1”	6 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
1-1/4”	7 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
1-1/2”	8 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
2”	8 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
2-1/2”	9 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
3”	10 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
3-1/2”	11 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4
4”	12 feet	ANSI/MSS SP-69 & SP-58 Tables 3 & 4

C. Ductwork: Hangers and supports for rectangular and round ductwork shall be designed in accordance with the latest adopted edition of the SMACNA HVAC Duct Construction Standards. Vertical duct supports shall also be designed in accordance with the latest adopted edition of the SMACNA HVAC Duct Construction Standards. Note that the SMACNA HVAC Duct Construction Standards require that duct hangers also be installed within 2 feet of duct elbows and within 4 feet of duct branch fittings.

D. Rectangular Ducts: Maximum spacing and strap and/or hanger rod sizes shall be in accordance with SMACNA HVAC Duct Construction Standards Table 4.1.

E. Round Ducts: Maximum spacing and strap and/or hanger rod sizes shall be in accordance with SMACNA HVAC Duct Construction Standards Table 4.2.

1.3 SUMMARY

A. This section includes the following:
   1. Metal Pipe Hangers and Supports
   2. Thermal Hanger Shield Inserts
   3. Fastener Systems
   4. Pipe Stands
   5. Ductwork Supports
   6. Equipment Stands
   7. Equipment Supports

B. Related Requirements: All hangers and support systems shall be designed, selected, and installed by the Contractor to comply with the requirements listed in Section 230540 (Seismic Bracing for HVAC Systems).

C. Costs for hanger, support, and seismic bracing systems complying with the requirements listed herein are the responsibility of the Contractor and shall be included in the Contractor's bid. No extra cost will be allowed for failure to include the associated costs in the Contractor's bid.

D. In no case shall hangers and/or supports for HVAC piping, ductwork, or equipment be attached to a metal roof deck, unless provisions or allowances are explicitly shown on the structural drawings.

1.4 SUBMITTALS

A. Product Data: For each type of product.

B. Shop Drawings: Show fabrication and installation details for the following (Include product data for all components):
   1. Metal Framing (Strut) Systems
   2. Trapeze Pipe Hangers
   3. Pipe Stands
   4. Ductwork Supports
   5. Equipment Supports

C. Delegated Design Submittals: Provide comprehensive, all-inclusive, delegated design submittals for all listed items. Submittals shall comply with all performance requirements and design criteria, including analysis data, signed and sealed by the qualified professional engineer responsible for their preparation.
   1. Details for fabrication and assembly of trapeze hangers.
   2. Design calculations utilized for designing the trapeze hangers.
   3. Design details and calculations for ductwork and equipment supports.

D. The work of this section shall be coordinated with the requirements for the Contractor furnished seismic design submittal for hangers and supports specified in Section 230540 (Seismic Bracing for HVAC Systems). Design and detailing of seismic bracing, hangers, and supports is the responsibility of the Contractor.

E. Submittals shall be fully coordinated with the structural drawings and shall include all applicable structural and seismic attachment details. Locations and the methods of attachment of hangers and supports to the main structural frame shall comply with the limitations specified in the structural drawings.

F. Submittals shall include all support anchorage loads and vectors broken out by discrete load type. Each specific load shall be indicated in the submittals and the structural element that the support is attached to shall be clearly depicted/identified.

G. Shop drawing submittals will be reviewed by both the design mechanical engineer and the design structural engineer (structural engineer when applicable).

1.5 QUALITY ASSURANCE

A. Structural Steel Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M (Structural Welding Code - Steel).

B. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code, Section IX.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Delegated Design: Where required, engage a licensed professional engineer (licensed in the state where the project is located), to design trapeze pipe hangers/supports, ductwork hangers/supports, & equipment hangers/supports.

B. Structural Performance: Hangers and supports for HVAC piping, ductwork, and equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE Standard 7-16.

1. Design hangers/supports for piping, including pipe stands, capable of supporting combined weight of supported systems, system contents, and test water.
2. Design hangers/supports for ductwork and associated accessories.
3. Design equipment hangers/supports capable of supporting combined operating weight of supported equipment, including connected systems and components.
4. Design seismic restraint hangers and supports for piping, ductwork, and equipment. See Section 230540 (Seismic Bracing for HVAC Systems).
5. Design of connections for hangers, supports, and bracing shall comply with the requirements indicated on the structural drawings.

2.2 GENERAL MATERIALS

A. Aluminum: ASTM B221.

B. Carbon Steel: ASTM A1011/A1011M.

C. Structural Steel: ASTM A36/A36M, carbon steel plates, shapes, and bars; galvanized.

D. Stainless Steel: ASTM A240/A240M.

E. Threaded Rods: Continuously threaded. Zinc plated or galvanized steel for indoor applications and stainless steel for outdoor applications. Mating nuts and washers shall be same or similar materials as rods.

F. Grout: ASTM C1107/C1107M, factory mixed and packaged, dry hydraulic cement, non-shrink and non-metallic grout; suitable for interior and exterior applications.

1. Properties: Non-staining, non-corrosive, and non-gaseous.
2. Design Mix: 5,000 psi, 28 day compressive strength.

2.3 HVAC EQUIPMENT HANGERS AND SUPPORTS

A. Provide delegated design as applicable for the specific equipment.

2.4 DUCTWORK HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Galvanized steel rods and nuts.

B. Hanger Rods for Corrosive Environments: Electro-galvanized, all-thread rods, or galvanized rods with threads painted with zinc-chromate primer after installation.

C. Strap and Rod Sizes: Comply with SMACNA HVAC Duct Construction Standards - Metal and Flexible, Table 5-1 (Minimum Hanger Sizes for Rectangular Ducts) and Table 5-2 (Minimum Hanger Sizes for Round Ducts).

D. Steel Cables for Galvanized Steel Ducts: Galvanized steel complying with ASTM A603.

E. Steel Cables for Stainless Steel Ducts: Stainless steel complying with ASTM A492.

F. Steel Cable End Connections: Galvanized steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic locking and clamping device.

G. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

H. Trapeze and Riser Supports
   1. Supports for Galvanized Steel Ducts: Galvanized steel shapes and plates.
   2. Supports for Stainless Steel Ducts: Stainless steel shapes and plates.
   3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

2.5 HVAC PIPE HANGERS AND SUPPORTS

A. Carbon Steel Pipe Hangers and Supports
   1. Description: MSS SP-58, Types 1 through 58, factory fabricated components.
   2. Galvanized Metallic Coatings: Pre-galvanized, hot dip galvanized, or electro-galvanized.
   3. Non-Metallic Coatings: Plastic coated or epoxy powder coated.
   4. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support the bearing surface of the piping.
   5. Hanger Rods: Continuous thread rod, nuts, and washers made of carbon steel.

B. Stainless Steel Pipe Hangers and Supports
   1. Description: MSS SP-58, Types 1 through 58, factory fabricated components.
   2. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
   3. Hanger Rods: Continuous thread rod, nuts, and washers made of carbon steel.

C. Copper Pipe and Tube Hangers
   1. Description: MSS SP-58, Types 1 through 58, copper plated steel, factory fabricated components.
   2. Hanger Rods: Continuous thread rod, nuts, and washers made of carbon steel.

2.6 HANGER AND SUPPORT MATERIALS

A. Additional hanger and support requirements are listed in sections specifying piping, ductwork, and equipment.

B. Comply with MSS SP-58 for pipe hanger selections and applications that are not specified in piping system sections.

C. Use hangers and supports with galvanized metallic coatings for piping, ductwork, and equipment that will not have field applied finish.

D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

E. Use carbon steel pipe hangers and supports metal trapeze pipe hangers and metal framing systems and attachments for general service applications.

F. Use copper plated pipe hangers and copper or stainless steel attachments for copper piping and tubing.

G. Use padded hangers for piping that is subject to scratching.

H. Use thermal hanger shield inserts for insulated piping and tubing.

I. Horizontal Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system sections, install the following types:

1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of non-insulated or insulated, stationary pipes 1/2” thru 30” size.
2. Yoke Type Pipe Clamps (MSS Type 2): For suspension of up to 1050°F, pipes 4” thru 24” size, requiring up to 4 inches of insulation.
3. Carbon or Alloy Steel, Double Bolt Pipe Clamps (MSS Type 3): For suspension of pipes 3/4” thru 36” size, requiring clamp flexibility and up to 4 inches of insulation.
4. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes 1/2” thru 24” size if little or no insulation is required.
5. Pipe Hangers (MSS Type 5): For suspension of pipes 1/2” thru 4” size, to allow off center closure for hanger installation before pipe erection.
6. Adjustable Swivel Split or Solid Ring Hangers (MSS Type 6): For suspension of non-insulated, stationary pipes 3/4” thru 8” size.
7. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of non-insulated, stationary pipes 1/2” thru 8” size.
8. Adjustable Band Hangers (MSS Type 9): For suspension of non-insulated, stationary pipes 1/2” thru 8” size.
9. Adjustable, Swivel Ring Band Hangers (MSS Type 10): For suspension of non-insulated, stationary pipes 1/2” thru 8” size.
10. Split Pipe Ring with or without Turnbuckle Hangers (MSS Type 11): For suspension of non-insulated, stationary pipes 3/8” thru 8” size.
11. Extension Hinged or Two Bolt Split Pipe Clamps (MSS Type 12): For suspension of non-insulated, stationary pipes 3/8” thru 3” size.
12. U-Bolts (MSS Type 24): For support of heavy pipes 1/2” thru 30” size.
13. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
14. Pipe Saddle Supports (MSS Type 36): For support of pipes 4” thru 36” size, with steel pipe base stanchion support and cast iron floor flange or carbon steel plate.
15. Pipe Stanchion Saddles (MSS Type 37): For support of pipes 4” thru 36” size, with steel pipe base stanchion support and cast iron floor flange or carbon steel plate, and with U-bolt to retain pipe.

16. Adjustable Pipe Saddle Supports (MSS Type 38): For stanchion type support for pipes 2-1/2” thru 36” size if vertical adjustment is required, with steel pipe base stanchion support and cast iron floor flange.
17. Single Pipe Rolls (MSS Type 41): For suspension of pipes 1” thru 30” size , from two rods if longitudinal movement caused by expansion and contraction might occur.
18. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes 2-1/2” thru 24” size, from single rod if horizontal movement caused by expansion and contraction might occur.
19. Complete Pipe Rolls (MSS Type 44): For support of pipes 2” thru 42” size if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is unnecessary.
20. Pipe Roll and Plate Units (MSS Type 45): For support of pipes 2” thru 24” size if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is unnecessary.
21. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes 2” thru 30” size if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.

J. Vertical Piping Clamps: Unless otherwise indicated and except as specified in piping system sections, install the following types:
   1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers 3/4” thru 24”.
   2. Carbon or Alloy Steel Riser Clamps (MSS Type 42): For support of pipe risers 3/4” thru 24” size if longer ends are required for riser clamps.

K. Hanger Rod Attachments: Unless otherwise indicated and except as specified in piping system sections, install the following types:
   1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.
   2. Steel Clevises (MSS Type 14): For 120 to 450°F piping installations.
   3. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
   4. Malleable Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
   5. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450°F piping installations.

L. Building Attachments: Unless otherwise indicated and except as specified in piping system sections, install the following types:
   1. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
   2. Top Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joist construction, to attach to top flange of structural shape.
   3. Side Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
   4. Center Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
   5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
   6. C-Clamps (MSS Type 23): For structural shapes.
   7. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
   8. Side Beam Clamps (MSS Type 27): For bottom of steel I-beams.
   9. Steel Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
   10. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.

11. Malleable Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
12. Welded Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:
    a. Light (MSS Type 31): 750 lbs.
    b. Medium (MSS Type 32): 1500 lbs.
    c. Heavy (MSS Type 33): 3000 lbs.
13. Side Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
14. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
15. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.

M. Saddles and Shields: Unless otherwise indicated and except as specified in piping system sections, install the following types:
    1. Steel Pipe Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
    2. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
    3. Thermal Hanger Shield Inserts: For supporting insulated pipe.

N. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system sections, install the following types:
    1. Restraint Control Devices (MSS Type 47): Where indicated to control piping movement.
    2. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches.
    3. Spring Cushion Roll Hangers (MSS Type 49): For equipping Type 41, roll hanger with springs.
    4. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.
    5. Variable Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from hanger.
    6. Variable Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from base support.
    7. Variable Spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from trapeze support.
    8. Constant Supports: For critical piping stress and if necessary, to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load adjustment capability. These supports include the following types:
        a. Horizontal (MSS Type 54): Mounted horizontally.
        b. Vertical (MSS Type 55): Mounted vertically.
        c. Trapeze (MSS Type 56): Two vertical type supports and one trapeze member.

O. Comply with MSS SP-58 for trapeze pipe hanger selections and applications that are not specified in piping system sections.

P. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system sections.

Q. Use powder actuated fasteners and mechanical expansion anchors instead of building attachments where required in concrete construction.

2.7 TRAPEZE PIPE HANGERS

A. Description: MSS SP-58, Type 59, shop or field fabricated pipe support assembly made from structural carbon steel shapes with MSS SP-58 carbon steel hanger rods, nuts, saddles, and U-bolts.

2.8 METAL FRAMING (STRUT) SYSTEMS

A. Metal Framing Manufacturers Association (MFMA) Metal Framing Systems

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include the following, or approved equal:

   B-line
   Unistrut
   Flex-Strut
   G-Strut
   Miro Industries

2. Description: Shop or field fabricated, pipe support assembly made of steel channels, accessories, fittings, and other components for supporting multiple parallel pipes.
3. Standard: Comply with MFMA-4 factory fabricated components for field assembly.
4. Channels: Continuous slotted carbon steel channel with in-turned lips.
5. Channel Width: Selected for applicable load criteria.
6. Channel Nuts: Formed or stamped nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
7. Hanger Rods: Continuous thread rod, nuts, and washers made of carbon steel.
8. Metallic Coating: Zinc dichromate finish applied over an electro-galvanized zinc plating.

2.9 THERMAL HANGER SHIELD INSERTS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include the following, or approved equal:
   Pipe Shields
   nVent/Caddy
   Buckaroos

B. Standard Insulation Insert Material for Cold Piping: Polyisocyanurate high density insulation, with 125 psi minimum compressive strength, a flame spread/smoke developed rating of 25/50 or less, and vapor barrier.

C. Standard Insulation Insert Material for Hot Piping: Polyisocyanurate high density insulation, with 125 psi minimum compressive strength, a flame spread/smoke developed rating of 25/50 or less; or Calcium Silicate with 100 psi minimum compressive strength.

D. Structural/Seismic Insert Material for Cold Piping: Polyisocyanurate high density insulation, with a minimum density of 14 lbs/ft^3, a minimum compressive strength of 900 psi, and a flame spread/smoke developed rating of 25/50 or less. Structural inserts shall be used as recommended by the insert manufacturer to meet load ratings.

E. Structural/Seismic Insert Material for Hot Piping: Calcium Silicate with a minimum density of 28 lbs/ft^3 and a minimum compressive strength of 900 psi. Structural inserts shall be used as recommended by the insert manufacturer to meet load ratings.

F. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.

G. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.

H. Insert Length: Extend 2 inches beyond sheet metal shield for piping operating below ambient air temperature.

I. Provide a vapor barrier steel jacket around insulation. Insulation jackets shall be galvanized steel conforming to ASTM A653. Hanger bearing surface shall consist of a galvanized sheet metal insulation protection shield or casing.

J. Thermal hanger supports shall be load rated. Load ratings shall be established by the pipe support manufacturer based upon testing and analysis in conformance with the current edition of following codes and standards: ASME B31.1, MSS SP-68, SP-69, and SP-89.

K. Unless otherwise indicated, thermal hanger supports shall be as indicated in the following schedule, or approved equal. The listed model numbers are based on Pipe Shields.
   1. Pipe supported on hangers: Models A2000, A4000, A9000, and D3000 series.
   2. Pipe supported on flat surfaces: Models A2000, A4000, A6000, A7000, A7200, and A7400.
   3. Pipe Supported on pipe rolls: Models A4000, A6000, A8200, and A8400.
   4. Pipe supported on slides and guides: Model B series.
   5. Riser pipe supports: Model E series.

L. The selected model(s) shall conform to pipe service, support style, and support spacing.

M. Pipe support spacing shall be in accordance with the manufacturer's recommendations, but in no case shall exceed the maximum spacing required by ASME B31.1.

2.10 FASTENER SYSTEMS

A. Powder Actuated Fasteners: Threaded steel stud, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used. Powder actuated fasteners may only be utilized for point loads of 50 lbs or less.
   1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include the following, or approved equal:
      Hilti
      ITW Ramset (Red Head)
      Simpson Strong-Tie

B. Mechanical Expansion Anchors: Insert wedge type anchors for use in hardened portland cement concrete; with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
   1. Indoor Applications: Zinc-coated stainless steel.
   2. Outdoor Applications: Stainless steel.
   3. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include the following, or approved equal:
      Hilti
      ITW Ramset/Red Head
      B-line

2.11 PIPE STANDS

A. General Requirements for Pipe Stands: Shop or field fabricated assemblies made of manufactured corrosion resistant components to support roof mounted piping.

B. Compact Pipe Stand

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include the following, or approved equal:

   Miro Industries
   PHP Systems/Design
   Rooftop Support Systems

2. Description: Single base unit with integral rod roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration.
3. Base: Single, vulcanized rubber, molded polypropylene, or polycarbonate.
4. Hardware: Galvanized steel or polycarbonate.
5. Accessories: Protection pads.

C. Low Profile, Single Base, Single Pipe Stand

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include the following, or approved equal:

   Miro Industries
   PHP Systems/Design
   Rooftop Support Systems

2. Description: Single base with vertical and horizontal members, and pipe support, for roof installation without membrane protection.
3. Base: Single, vulcanized rubber, molded polypropylene, or polycarbonate.
4. Vertical Members: Two galvanized steel, continuous thread 1/2 inch rods.
5. Horizontal Member: Adjustable horizontal, galvanized steel pipe support channels.
6. Pipe Supports: Roller strut clamps, clevis hanger, or swivel hanger.
7. Hardware: Galvanized steel.
8. Accessories: Protection pads.
9. Height: 12 inches above roof, or as indicated on the drawings.

D. High Profile, Multiple Pipe Stand

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include the following, or approved equal:

   Miro Industries
   PHP Systems/Design
   Rooftop Support Systems

2. Description: Assembly of bases, vertical and horizontal members, and pipe supports, for roof installation without membrane penetration.
3. Bases: Two or more vulcanized rubber molded polypropylene insert material.
4. Vertical Members: Two or more galvanized steel channels.
5. Horizontal Members: One or more adjustable height, galvanized steel pipe supports.
6. Pipe Supports: Roller strut clamps, clevis hanger, swivel hanger.
7. Hardware: Galvanized steel.
8. Accessories: Protection pads**,** 1/2 inch continuous thread rod.
9. Height: 24 inches above the roof or as indicated on the drawings.

E. Curb Mounted Type Pipe Stands: Shop or field fabricated pipe supports made from structural steel shapes, continuous thread rods, and rollers, for mounting on permanent stationary roof curb.

2.12 EQUIPMENT SUPPORTS

A. Description: Welded, shop or field fabricated equipment supports made from structural carbon steel shapes.

2.13 OUTDOOR EQUIPMENT STANDS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include the following, or approved equal:

Miro Industries
Rooftop Support Systems

B. Description

1. Description: Individual foot supports with elevated adjustable channel cross bars and clamps/fasteners/bolts for ground or roof supported outdoor equipment components, without roof membrane penetration, in a pre-fabricated system that can be modularly assembled on site.
2. Foot Material: Rubber or polypropylene.
3. Rails Material: Hot dip galvanized carbon steel.
4. Wind/Sliding Load Resistance: Up to 120 mph, or as indicated on the structural drawings.

PART 3 - EXECUTION

3.1 APPLICATION

A. Comply with all requirements in other section of the specifications for firestopping materials and installation for penetrations through fire rated walls, ceilings, and assemblies.

B. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus 200 lbs.

3.2 HANGER AND SUPPORT INSTALLATION

A. Metal Pipe Hanger Installation: Comply with MSS SP-58. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.

B. Metal Trapeze Pipe Hanger Installation: Comply with MSS SP-58. Arrange for grouping of parallel runs of horizontal piping, and support together on field fabricated trapeze pipe hangers.

1. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified for individual pipe hangers.
2. Field fabricate from ASTM A36/A36M, carbon-steel shapes selected for loads being supported. Weld steel according to AWS D1.1/D1.1M.

C. Thermal Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.

D. Fastener System Installation
   1. Install powder actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder actuated tool manufacturer. Install fasteners according to powder actuated tool manufacturer's operating manual.
   2. Install mechanical expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

E. Pipe Stand Installation
   1. Pipe Stand Types Except Curb Mounted Type: Assemble components and mount on smooth roof surface. Do not penetrate the roof membrane.
   2. Curb Mounted Type Pipe Stands: Assemble components or fabricate pipe stands and mounts on a permanent, stationary roof curb.

F. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.

G. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.

H. Install lateral bracing with pipe hangers and supports to prevent swaying.

I. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, 2-1/2” pipe size and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.

J. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.

K. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.

L. Insulated Piping
   1. Attach clamps and spacers to piping.
      a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
      b. Piping Operating below Ambient Air Temperature: Use thermal hanger shield insert with clamp sized to match OD of insert.
      c. Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.
   2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation. Optional: Thermal hanger shield inserts may be used. Include steel weight distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.
   3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees. Optional: Thermal hanger shield inserts may be used. Include steel weight distribution plate for pipes 4” and larger if pipe is installed on rollers.
   4. Shield Dimensions for Pipe: Not less than the following:
      a. 1/2” to 3-1/2” pipe: 12 inches long and 0.048 inch thick.
      b. 4” and 5” pipe: 18 inches long and 0.06 inch thick.
      c. 8” thru 14” pipe: 24 inches long and 0.075 inch thick.
      d. 16” thru 24” pipe: 24 inches long and 0.105 inch thick.
   5. Pipes 8” and Larger: Include wood or reinforced calcium silicate insulation inserts of length at least as long as the protective shield.
   6. Thermal Hanger Shields: Install with insulation same thickness as piping insulation.

3.3 EQUIPMENT HANGERS/SUPPORTS

A. Fabricate structural steel supports to suspend equipment from structure overhead or structural steel stands to support equipment above the floor.

B. Grouting: Place grout under supports for equipment and make bearing surface smooth.

C. Provide lateral bracing for equipment supports to prevent swaying.

3.4 DUCTWORK HANGERS/SUPPORTS

A. Fabricate structural steel supports to suspend ductwork from structure overhead.

B. Fabricate structural steel stands to support ductwork above the floor (when indicated on the drawings). Provide lateral bracing for ductwork supports to prevent swaying.

3.5 METAL FABRICATIONS

A. Cut, drill, and fit miscellaneous metal fabrications for trapeze pipe hangers and equipment supports.

B. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.

C. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:

1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
2. Obtain fusion without undercut or overlap.
3. Remove welding flux immediately.
4. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

3.6 ADJUSTING

A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.

B. Trim excess length of continuous thread hanger and support rods to 1-1/2 inches.

3.7 PAINTING

A. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field painted surfaces. Apply paint by brush or spray to provide a minimum dry film thickness of 2.0 mils.

B. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing repair paint to comply with ASTM A780/A780M.

END OF SECTION

SECTION 23 05 40 - SEISMIC BRACING FOR HVAC SYSTEMS

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Section 230000 (Heating, Ventilating, and Air Conditioning), Section 230500 (Basic Materials and Methods for HVAC), and Section 230530 (Hangers and Supports for HVAC Systems) are hereby made a part of this section.

1.2 GENERAL

A. Seismic bracing for mechanical systems (equipment, ductwork, piping, and conduit) shall comply with all applicable requirements of the latest adopted edition of the International Building Code (IBC) including all applicable provisions of the latest adopted edition of the American Society of Civil Engineers (ASCE) Minimum Design Loads for Buildings and Other Structures (ASCE Standard 7-16). Basic seismic design criteria for each project shall be as listed on the structural drawings for that project.

B. The anchorage calculations shall show compliance with the latest adopted edition of the American Concrete Institute (ACI) Standards, Handbooks, and Manuals where anchoring to concrete for the project-specific loads and conditions, including project specific calculations for anchors, clips, and fasteners.

C. Anchorage calculations for seismic roof curbs shall be included in seismic roof curb submittal, including a stamped plan or detail showing the anchorage requirement. This detail shall include specific anchor type, diameter, embedment, and layout or spacing. The anchorage calculation shall show compliance with the American Concrete Institute (ACI) where anchoring to concrete for the specific loads and conditions present, including project specific calculations for anchors, clips, and fasteners

D. Compliance with the applicable seismic bracing requirements for equipment, ductwork, piping, and conduit shall be accomplished utilizing the most current version of one of the following design manuals, or approved equal.

International Seismic Application Technology (ISAT) Design Manual

Mason Industries Seismic Restraint Design Manual

Vibro-Acoustics Seismic Design Manual

SMACNA Seismic Restraint Manual (Guidelines for Mechanical Systems)

E. Component Importance Factors (Ip) for all equipment, ductwork, piping, and conduit shall be determined and assigned in accordance with ASCE Standard 7-16 Section 13.1.3.

F. Design and detailing of seismic bracing, hangers, and supports for equipment, ductwork, piping, and conduit is the responsibility of the Contractor.

G. Design of connections for hangers, supports, and bracing shall comply with the requirements indicated on the structural drawings (when provided).

H. The work of this section shall be coordinated with the requirements for the Contractor furnished delegated design submittal for hangers and supports specified in Section 230530 (Hangers and Supports for HVAC Systems). Design and detailing of seismic bracing, hangers, and supports is the responsibility of the Contractor.

1.3 SUBMITTALS

A. The Contractor shall provide the required number of seismic shop drawing submittal sets for review and approval by the Engineer. Submittals shall include a comprehensive set of shop drawings clearly depicting the seismic bracing requirements for all equipment, ductwork, piping, and conduit. Any piping or conduit that does not require seismic bracing shall be specifically identified in the submittal, and the reason for exemption shall be provided. Cite any and all references for the exemption. In cases where seismic bracing is not required due to the supported items being less than 12 inches below the supporting structure, a single note may be provided to cover those locations.

B. Submittals shall be fully coordinated with the structural drawings and shall include all applicable structural attachment details. Seismic bracing shop drawings shall include all vertical support anchorage loads and all seismic bracing anchorage loads. Each specific load shall be indicated and the structural element that the support is attached to shall be clearly depicted/identified. Seismic bracing submittals shall be stamped and signed by a structural or civil engineer with current registration licensed in the State of Nevada (or licensed in the state where the project is located, if the project is located outside the State of Nevada).

C. Seismic shop drawing submittals will be reviewed by both the design mechanical engineer and the design structural engineer.

1.4 SITE VISITS (QUALITY CONTROL)

A. An authorized representative of the seismic bracing system manufacturer shall visit the job site during the construction period to confirm that the seismic bracing installation complies with the shop drawings, with all applicable code requirements, and with the seismic bracing system manufacturer’s written installation requirements and associated details. As a minimum, an authorized representative shall visit the site when the seismic bracing installation is complete (and prior to installation of the ceilings).

B. A written report shall be issued within one week the site visit summarizing the observations made during the site visit and listing all required corrective actions and/or deficiencies. The report shall be made available to both the design mechanical engineer and the design structural engineer.

C. After all equipment installation is complete and all seismic bracing has been verified, the authorized representative that conducted the field verification shall issue a letter certifying that the installation is complete and that the installation complies with the specified requirements

D. Site visits shall be coordinated with the Owner and shall be scheduled in writing a minimum of one week prior to the proposed site visit date.

END OF SECTION

SECTION 23 07 00 - HVAC SYSTEMS INSULATION

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

1.2 WORK INCLUDED

A. Types of mechanical insulation specified in this section include the following:

1. Piping Systems Insulation

   Heating Water Supply and Return Piping
   Heat Recovery Piping
   Condensate Drain Piping
   Refrigerant Piping

2. Ductwork Systems Insulation

   Supply Air and Return Air Ducts
   Outside Air Intake Ducts

3. Equipment Insulation

   Heat Recovery Water Equipment
   Heat Recovery Water Air Separators
   Heat Recovery Water Pumps
   Heating Hot Water Pumps
   Removable Insulating Jackets

1.3 QUALITY ASSURANCE

A. Installer Qualifications: Insulation specialty firm with at least 5 years successful installation experience on projects with mechanical insulations similar to that required for this project.

B. SMACNA Compliance: Comply with applicable portions of Sheet Metal and Air Conditioning Contractor's National Association (SMACNA) recommendations for all work in this section.

C. ASHRAE Standards: Comply with applicable portions of American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) recommendations for all work in this section.

D. NFPA Standards: Comply with applicable portions of ANSI/NFPA Standard 90A (Standard for the Installation of Air Conditioning and Ventilating Systems) and ANSI/NFPA 90B (Standard for the Installation of Warm Air Heating and Air Conditioning Systems) for all work in this section.

E. NAIMA Standards: Comply with all applicable portions of the North American Insulation Manufacturers Association (NAIMA) standards for all related work in this section.

F. MICA Standards: Comply with all applicable portions of the Midwest Insulation Contractors Association standards for all related work in this section.

G. Install thermal insulation products on equipment in accordance with the manufacturer's written instructions and in accordance with recognized industry practices to ensure that insulation serves its intended purpose.

1.4 SUBMITTALS

A. Product Data: Submit manufacturer's technical product data and installation instructions for each type of insulation. Submit schedule showing manufacturer's product number, k-Value, thickness, density, and furnished accessories for each mechanical system requiring insulation. Include complete description of installation methods with this submittal.

PART 2 - PRODUCTS

2.1 PIPE INSULATION MATERIALS

A. General: All pipe insulation conductivities and thicknesses shall meet or exceed the requirements listed in 2018 International Energy Conservation Code Table C403.11.3. All conductivity values listed in this specification section are in Btu-in/(hr-ft^2-°F).

B. Flame/Smoke Spread Ratings: Insulation installed inside the building shall consist of composite mechanical insulation (insulation, jackets, coverings, sealers, mastics, and adhesives) with a flame spread rating of 25 or less and a smoke developed index of 50 or less, per ASTM E84.

C. Aluminum Jacketing shall be Johns Manville ‘JM Aluminum Jacketing’ with ‘Polyfilm Moisture Barrier’ and stucco-embossed finish, or approved equal, and shall be installed in conformance with the manufacturer’s written instructions. Secure jacketing with 3/4” wide Type 304 stainless steel bands at 12” on center. Finish all cold fittings as required to provide a vapor-tight seal. Aluminum and/or stainless steel jacketing shall be provided in the following thicknesses:

1. For Insulation Outside Diameters under 8”: .016 inch thick jacketing
2. For Insulation Outside Diameters 8” thru 24”: .024 inch thick jacketing

D. Lower Level Exposed in all piping applications shall mean any exposed pipe in a mechanical room, mezzanine area, or other accessible space that is less than 8’-0” above finished floor.

E. Higher Level Exposed in all piping applications shall mean any exposed pipe in a mechanical room, mezzanine area, or other accessible space that is 8’-0” or more above finished floor.

F. Fiberglass Insulation (Concealed Applications)

1. Fiberglass insulation shall be Johns Manville Microlok HP, or approved equal, with factory-applied fire-retardant ASJ jacket, self-sealing laps, and shall be applied per manufacturer's written recommendations. Conductivity shall be 0.23 at 75°F, 0.25 at 125°F, and 0.28 at 200°F. Insulation shall be rated for applications from 0°F up to 850°F. Insulation flame spread/smoke developed rating shall be 25/50 or less in accordance with ASTM E84.
2. Insulate and cover all fittings with Johns Manville Zeston Series 2000 standard gauge pre-molded fitting covers secured with serrated tacks, adhesive, and/or Zeston Z-Tape.
3. Install a segment of rigid calcium silicate insulation at each pipe hanger for pipe sizes 2-1/2 inches and larger.
4. Finish all cold fittings with Zeston Z-tape to provide a vapor-tight seal.
5. Seal all raw ends of insulation with Childers CP-10 weather barrier sealant, or equal.
6. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products which may be incorporated in the work include the following, or approved equal:

   Johns Manville
   Knauf
   Owens Corning

G. Fiberglass Insulation (Lower Level Exposed Applications)

1. Fiberglass insulation shall be Johns Manville Microlok HP, or approved equal, with factory-applied fire-retardant ASJ jacket, self-sealing laps, and shall be applied per manufacturer's written recommendations. Conductivity shall be 0.23 at 75°F, 0.25 at 125°F, and 0.28 at 200°F. Insulation shall be rated for applications from 0°F up to 850°F. Insulation flame spread and smoke developed rating shall be 25/50 or less in accordance with ASTM E84. Lower level exposed piping shall be covered with aluminum jacketing.
2. Insulate and cover all fittings with aluminum jacketing and aluminum fitting covers.
3. Install a segment of rigid calcium silicate insulation at each pipe hanger for pipe sizes 2-1/2 inches and larger.
4. Finish all cold fittings with Zeston Z-tape to provide a vapor-tight seal.
5. Seal all raw ends of insulation with Childers CP-10 weather barrier sealant, or equal.
6. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products which may be incorporated in the work include the following, or approved equal:

   Johns Manville
   Knauf
   Owens Corning

H. Fiberglass Insulation (Higher Level Exposed Applications)

1. Fiberglass insulation shall be Johns Manville Microlok HP Ultra with performance characteristics as specified for Johns Manville Microlok HP insulation plus a factory-applied polypropylene coating that is cleanable/washable.
2. Insulate and cover all fittings with Johns Manville Zeston Series 2000 standard gauge pre-molded fitting covers secured with serrated tacks, adhesive, and/or Zeston Z-Tape.
3. Install a segment of rigid calcium silicate insulation at each pipe hanger for pipe sizes 2-1/2 inches and larger.
4. Finish all cold fittings with Zeston Z-tape to provide a vapor-tight seal.
5. Seal all raw ends of insulation with Childers CP-10 weather barrier sealant, or equal.
6. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products which may be incorporated in the work include the following, or approved equal:

   Johns Manville
   Knauf
   Owens Corning

2.2 HEATING WATER PIPING 141°F THRU 200°F (INDOORS)

A. Insulate lower level exposed heating hot water supply and return piping with fiberglass insulation covered with aluminum jacketing and aluminum fitting covers.

B. Insulate higher level exposed heating hot water supply and return piping with fiberglass insulation with polyurethane coated ASJ jacketing and heavy gauge pre-molded fitting covers.

C. Insulate concealed heating hot water supply and return piping with fiberglass insulation covered with ASJ jacketing and heavy gauge pre-molded fitting covers.

D. Minimum Insulation Thickness

1. Piping 3/4 inch and smaller: 1-1/2 inch
2. Piping 1 inch thru 1-1/4 inch: 1-1/2 inch
3. Piping 1-1/2 inch thru 3-1/2 inch: 2 inch
4. Piping 4 inch thru 6 inch: 2 inch
5. Piping 8 inch and larger: 2 inch

2.3 HEAT RECOVERY PIPING (INDOORS)

A. Insulate lower level exposed heat pump loop supply and return piping with fiberglass insulation covered with aluminum jacketing and aluminum fitting covers.

B. Insulate higher level exposed heat pump loop supply and return piping with fiberglass insulation with polyurethane coated ASJ jacketing and heavy gauge pre-molded fitting covers.

C. Insulate concealed heat pump loop supply and return piping with fiberglass insulation covered with ASJ jacketing and heavy gauge pre-molded fitting covers

D. Minimum Insulation Thickness

1. All pipe sizes: 1 inch

2.4 CONDENSATE DRAIN PIPING (INDOORS)

A. Insulate condensate drain piping installed inside the building with fiberglass Insulation. Insulation is not required on condensate overflow drain piping.

1. Minimum Insulation Thickness for all pipe sizes: 1/2 inch

2.5 REFRIGERANT PIPING INSULATION (INDOORS)

A. Insulate refrigerant suction piping installed indoors with 3/4 inch thick AP Armaflex closed cell foam pipe insulation. Flame spread and smoke developed rating shall be 25/50 or less in accordance with ASTM E84. Fittings and valves shall be covered with segmented sections of the pipe insulation installed in accordance with the insulation manufacturer's instructions. All joints between sections of insulation shall be sealed with Armaflex No. 520 adhesive.

B. Insulate both liquid and suction lines on mini-split system heat pumps and variable refrigerant systems that incorporate heat recovery using the aforementioned insulating materials.

2.6 REFRIGERANT PIPING INSULATION (OUTDOORS)

A. Insulate refrigerant piping installed outdoors with 1 inch thick Johns Manville Trymer 25-50 with vapor retarder film, covered with Polyguard ‘Alumaguard’ all-weather flexible weatherproofing jacketing. Note that Trymer 25-50 closed cell polyisocyanurate insulation is required on outdoor refrigerant piping because it does not expand and contract during weather extremes like AP Armaflex closed cell foam pipe insulation.

B. Insulate both liquid and suction lines on mini-split system heat pumps and variable refrigerant systems that incorporate heat recovery using the aforementioned insulating materials.

2.7 DUCTWORK INSULATION MATERIALS

A. General: All duct insulation R-Values and thicknesses shall meet or exceed the requirements listed in International Energy Conservation Code Section C403.11.1.

B. See Specification Section 233100 (HVAC Ductwork) for additional related requirements.

C. Ductwork Insulation (General)

1. All concealed supply air ductwork (rectangular and round) shall be externally insulated unless indicated otherwise on the drawings.
2. All concealed return air ductwork (rectangular and round) that is located in a return air plenum is not required to be insulated, unless indicated otherwise on the drawings.
3. All outside air ductwork is required to be insulated.

D. Ductwork Liner Insulation (See Specification Section 233100 (HVAC Ductwork).

E. External Duct Wrap Insulation

1. Unless indicated otherwise, wrap all concealed supply air and return air ductwork with 2-1/5 inch thick, 0.75 pcf density, fiberglass duct insulation with reinforced foil facing (Johns Manville Microlite FSK Type 75, or equal, with an R-value equal to 6.0).
2. Unless indicated otherwise, wrap all outside air ductwork with 2-1/5 inch thick, 0.75 pcf density, fiberglass duct insulation with reinforced foil facing (Johns Manville Microlite FSK Type 75, or equal, with an R-value equal to 6.0).
3. Any exposed supply air or return air ductwork that is indicated on the drawings to be insulated shall be insulated with Johns Manville PSK white or black insulation, or approved equal, with matching PSK seaming tape.
4. In addition to the insulation manufacturer's tape flap, all insulation seams shall be sealed with pressure-sensitive tape (Shurtape AF-984CT, or equal). Longitudinal seams shall have a 4 inch overlap of the foil facing secured with outward clinching staples and pressure sensitive tape.
5. In addition to the specified seam sealing procedure, secure insulation with 16 gauge galvanized wire tied on 16" centers and within 8 inches of insulation seams.
6. Secure insulation on the underside of ducts that are wider than 24 inches with either weld pins or with Duro-Dyne PBH Dynastick Fasteners adhered with Duro-Dyne PBACZVOC Dynastick Adhesive. Weld pins or fasteners shall be placed on 18" centers and within 6 inches of insulation seams. Any penetrations from pins in the insulation shall be sealed with pressure-sensitive tape. Galvanized wire ties are not required on any rectangular duct sections where the insulation is secured with pins and washers as outlined in this paragraph.

2.8 EQUIPMENT INSULATION MATERIALS

A. General: All equipment insulation R-Values and thicknesses shall meet or exceed the requirements listed in International Energy Conservation Code Section C403.11.3.

B. Heat Recovery Water Equipment

1. Insulate all heat recovery water equipment which does not have factory-applied insulation, including pump bodies and air separators. Do not insulate expansion tanks.
2. Flat insulation shall be 3 lb density fiberglass board with thickness as required for the operating temperature of the associated fluid inside the equipment. Insulation shall be Johns Manville Series 800 Spin-Glas with reinforced FSK jacket, Owens Corning Series 700 fiberglass board insulation with reinforced FSK jacket, or approved equal.
3. Curved insulation shall be 2.5 lb density semi-rigid fiberglass with thickness as required for the operating temperature of the associated fluid inside the equipment. Insulation shall be Johns Manville Micro-Flex large diameter pipe and tank insulation with reinforced FSK jacket, Owens Corning large diameter pipe and tank insulation with reinforced FSK jacket, or approved equal.
4. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products which may be incorporated in the work include the following, or approved equal:

   Johns Manville
   Knauf
   Owens Corning

C. Removable Insulating Jackets

1. Removable insulating jackets shall be provided for the following items:

   Heat Recovery water pumps
   Motorized control valves located indoors and/or outdoors
   Flanged valves located indoors and/or outdoors

2. Insulation and jacket material shall be rated for the operating temperature of the equipment and/or fluid being insulated. Insulating jackets shall be removable and reusable, thermal and acoustical insulating jackets, constructed of minimum 18 ounce material, and sewn with Kevlar thread.
3. Jackets for applications above 250°F (i.e., high temperature hot water and steam valves in exterior valve vaults) shall be fabricated with either silicone or PTFE coated fiberglass fabric inner and outer material, and minimum 4" thick needled fiberglass insulation (see pipe insulation section for required thickness based on pipe size and temperature). The inner layer shall include a stainless steel mesh liner.
4. Jackets for hot water applications 250°F and below (e.g., hot water valves in exterior valve vaults) shall be fabricated with PTFE-coated fiberglass fabric inner and outer material and minimum 2" thick needled fiberglass insulation (see pipe insulation section for required thickness based on pipe size and temperature).
5. Jackets for cold/chilled water applications shall be fabricated with PTFE-coated fiberglass fabric inner and outer material and 1" thick needled fiberglass insulation.
6. Insulating jackets shall be secured with stainless steel d-rings with straps and Velcro fasteners.
7. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products which may be incorporated in the work include the following, or approved equal:

   Insultech
   MIT International
   Thermal Energy Products

PART 3 - EXECUTION

3.1 INSTALLATION OF PIPING INSULATION

A. The term 'piping' used herein shall include pipe, valves, strainers, and fittings. Apply insulating cements to fittings, valves, and strainers, and trowel smooth to the thickness of adjacent covering. Covering on valves shall extend up to the bonnet. The covering cement shall be of the types specified herein.

B. Install all insulation products in accordance with the manufacturer's written instructions and in accordance with recognized industry practices.

C. Install insulation on pipe systems subsequent to installation of heat tracing, testing, and acceptance of tests.

D. Install insulation materials with smooth and even surfaces. Insulate each continuous run of piping with full length units of insulation, with single-cut pieces to complete each run. Do not use cut pieces or scraps abutting each other.

E. Clean and dry pipe surfaces prior to insulating. Butt insulation joints firmly together to ensure complete and tight fit over surfaces to be covered.

F. Extend piping insulation without interruption through walls, floors, and similar penetrations, except piping through fire walls.

G. Install pipe hangers on the outside of the insulation and not in contact with the pipe. Protect insulation as specified in Specification Section 230500 (Basic Materials and Methods for HVAC) under 'Hangers and Supports for Ductwork and Piping'.

H. Install a 6 inch long section of rigid insulation at each pipe saddle and/or hanger. Rigid sections shall be calcium silicate, except on chilled water piping where rigid sections shall be foamglas.

I. Seal all raw ends of insulation with Childers CP-10 weather barrier sealant, or approved equal.

3.2 INSTALLATION OF DUCTWORK INSULATION

A. Install insulation products in accordance with the manufacturer's written instructions and in accordance with these specifications.

B. Extend ductwork insulation without interruption through walls, floors, and similar penetrations, except ductwork through fire rated walls and where otherwise indicated.

C. Except where otherwise indicated, external duct insulation may be omitted on ductwork where internal duct liner insulation has been specified.

D. Except where otherwise indicated, ductwork exposed in conditioned spaces is not required to be insulated.

3.3 INSTALLATION OF EQUIPMENT INSULATION

A. Install all equipment insulation materials with smooth and even surfaces and on clean and dry surfaces. Replace any poorly fitted joints. Do not use mastic or joint sealer as filler for gapping joints and excessive voids resulting from poor workmanship.

B. Do not apply insulation to equipment, flues, breechings, or stacks while hot.

C. Do not insulate cleanouts, ASME stamps, or equipment manufacturer's nameplates. Provide neatly beveled edges at interruptions of insulation.

3.4 CARE AND CLEANING

A. Repair or replace broken, damaged, or otherwise defective insulation. Leave entire work in condition satisfactory to the Architect/Engineer. At completion, carefully clean equipment installed as part of this work. Leave systems and equipment in a satisfactory operating condition.

3.5 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like, and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 08 00 - TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

B. Section 230910 (Sequence of Operation) is hereby made a part of this section.

1.2 WORK INCLUDED

A. Temperature performance testing on all heat transfer equipment and/or components.

B. Test and balance of air distribution systems and associated equipment and apparatus.

C. Test and balance of hydronic distribution systems and associated equipment and apparatus.

D. Testing, setting, and adjusting speed and volume of systems, recording data, conducting tests, preparing and submitting reports, and recommending modifications to work as required by the contract documents.

E. Component types of testing, adjusting, and balancing specified in this section includes the following as applied to mechanical equipment:
Pumps
Piping Systems
Air Handling Units
Fans
Ductwork Systems
Terminal Units
Balancing Valves for HVAC Systems

1.3 QUALITY ASSURANCE

A. Balance Agency: Provide services and facilities of an independent agency that specializes in testing, analysis, and balancing of hydronic systems and air distribution for heating and/or cooling systems. Work shall be done by qualified engineering technicians and trained personnel, using instruments certified accurate to limits used in standard practice for testing and balancing of hydronic and air distribution for heating-cooling systems. The balance agency shall field test air and hydronic flows in accordance with the methods prescribed by the Associated Air Balance Council, National Standard Volume 1, latest edition.

B. The balance agency shall be a member of the Associated Air Balance Council. Subject to compliance with requirements, the balance agency shall be one of the following (no exceptions):

RS Analysis
Raglen System Balance

C. The balance agency shall submit the results of tests in this section to the Architect/Engineer for review and acceptance.

D. AABC Compliance: Comply with AABC ‘National Standards’ Volume 1, as applicable to mechanical air and hydronic distribution systems and associated equipment and apparatus.

E. Industry Standards: Comply with ASHRAE recommendations pertaining to measurements, instruments, and testing, adjusting and balancing, except as otherwise indicated.

F. Reference Standards

1. AABC (Associated Air Balance Council) AABC National Standards Volume 1.
2. ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers).

G. Test Instruments: Utilize test instruments and equipment for the test and balance work required, of type, precision, and capacity as recommended in AABC National Standards Volume 1.

1.4 SUBMITTALS

A. Provide a test and balance agenda that includes step-by-step testing and balancing procedures, test sheets, and schematic drawings, all being specific to the project.

B. Provide submittals to indicate the extent of work proposed. Submit certified test reports as hereinafter specified signed by test and balance technician/supervisor that performed test and balance work.

C. Include identification and types of instruments used and their most recent calibration date with submission of final test report.

D. The completed balance report shall be submitted for review and approval prior to requesting final observation of the project.

1.5 GENERAL REQUIREMENTS

A. The balance agency shall perform the following during the installation phase of systems:
   1. Study the design drawings and specifications and prepare a schedule to physically inspect mechanical equipment for the hydronic and air distribution systems to be tested and balanced. The Contractor shall provide the balance agency with one copy of the contract drawings and specifications, mechanical equipment submittals, and change orders necessary for proper balancing of the hydronic and air distribution systems.
   2. The balance agency shall make field inspections prior to closing in portions of systems to be balanced. The balance agency shall verify that all work, fittings, dampers, balancing devices, etc. are properly fabricated and installed as shown or specified and that the balance agency will be able to properly balance the systems.
   3. Prepare a testing and balancing schedule, test record forms, and necessary technical information regarding hydronic and air distribution systems for the installed heating and cooling equipment.
   4. Provide written documentation when the above noted items have been completed, (see example checklist provided at the end of this section). A single page letter signed off by the mechanical contractor and the test and balance agency will suffice.
   5. Recommend adjustments and/or corrections to mechanical equipment and hydronic and air distribution systems that are necessary for proper balancing of systems. Provide written documentation of the recommended items to the Architect/Engineer for review.

B. Patching Materials: Except as otherwise indicated, use same products as used by original installer for patching holes in insulation, ductwork, and housings which have been cut or drilled for test purposes, including access for test instruments, attaching jigs, and similar purposes. At tester's option, plastic plugs with retainers may be used to patch drilled holes in low pressure ductwork and housings (2” w.g. and below).

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.1 TESTING AND BALANCING

A. Upon completion of hydronic and air handling systems, the test and balance agency shall complete tests, analysis, and balance of hydronic and air handling systems for all heating and cooling equipment.

B. The report shall include as minimum, design and actual information for the following:
   1. All mechanical equipment scheduled on the drawings.

2. Motors, pumps, and fans: Horsepower, brake horsepower, revolutions per minute, actual amperage, full load rated amperage, pump flow and head data, etc.
3. Air handling unit fan, filter, and heating & cooling section performance data.
4. Supply, return, and exhaust fans: CFM, static pressure, and outlet velocity.
5. Pumps: Suction, discharge, and shutoff pressures.
6. Self-sensing pumps: Data as required for proper system operation, including balancing to the project specific self-sensing pump curves.
7. Terminal units: CFM, reheat coil pressure drop and air temperatures at inlet and outlet.
8. Inlets, outlets, and main branch ducts: CFM and air velocity.
9. Other information as required to establish completely balanced systems under design conditions.

3.2 BALANCING REQUIREMENTS

A. All air and water systems and devices shall be balanced to within +0% to +5% of design.

B. Make allowance for air filter resistance at time of tests (by false-loading the filter bank with cardboard or other suitable material such that the test results can be repeated). Test and balance all main supply and return air ducts to the design air quantities.

C. After final air and hydronic testing and balancing make necessary adjustments to obtain uniform temperatures as required during actual occupancy.

D. Take static pressure and air velocity readings with instruments that have been recently calibrated. Take final velocity readings with an Alnor velometer, Anemostat air meter, or vane type anemometer, all recently calibrated prior to testing. Include certified correction curves for each calibration as part of the record. Certify instruments are accurate to standards currently used in common practice for system balance work. Use test cones for diffusers.

E. Run tests with supply, return, and exhaust systems operating and doors, windows, etc. closed or under normal traffic. Conduct final testing with cooling coils under load to ensure that static pressures are or near design conditions.

F. Adjust deflection of supply outlets to ensure proper and uniform air distribution.

G. Work with the temperature control subcontractor in adjustment of automatic dampers, valves, thermostats, etc. as required to maintain proper temperatures in all portions of the building.

H. The Contractor responsible for installing heating, cooling, and ventilating equipment shall make any changes, additions, or modifications to dampers, fan drives, motor sheaves, pump impellers, motors, and other equipment as necessary for proper air and hydronic balance.

I. Balance of systems shall be reviewed by the Architect/Engineer. During this review the mechanical contractor shall furnish workmen, materials, ladders, etc. to enable the Architect/Engineer to witness all readings as may be directed. If any errors are found, the Testing and Balancing Agency shall readjust the system to the satisfaction of the Architect/Engineer.

J. See the Field Observation Checklist Example on the following page.

END OF SECTION

Field Observation Checklist (Example)			
YES	**NO**	**N/A**	
□	□	□	Is the ductwork intact?
□	□	□	Are any endcaps missing?
□	□	□	Are the access doors installed and secured tightly?
□	□	□	Are there openings in the ductwork?
□	□	□	Are any inlets or outlets missing?
□	□	□	Are the turning vanes installed correctly?
□	□	□	Is the ductwork, including fan inlets and outlets, installed according to the drawings and specifications?
□	□	□	Is the ductwork free of debris?
□	□	□	Are all duct dampers, including fire and smoke dampers, installed and accessible?
□	□	□	Are all terminal boxes, reheat coils, reheat components, etc. installed and accessible?
□	□	□	Does the return air have an unobstructed path from each conditioned space back to the unit?
□	□	□	Is the building architecturally complete?
□	□	□	Are all doors, windows, ceilings, partitions, etc. installed?
□	□	□	Are filters installed correctly and have frames that will not allow leakage?
□	□	□	Are the coils clean and properly installed?
□	□	□	Are the drive components installed?
□	□	□	Are the automatic control dampers installed in the correct locations?
□	□	□	Are the fan housings, plenums, etc. installed according to the drawings and specifications and properly sealed?
□	□	□	Are the flexible connections installed properly?
□	□	□	Are the fan wheels aligned properly with proper clearance between the fan and housing?
□	□	□	Are suitable traverse locations available?
□	□	□	Is the piping intact and free of leaks?
□	□	□	Are the pumps, piping, and equipment installed according to the drawings and specifications?
□	□	□	Are all valves, flow meters, and temperature-pressure taps installed to allow for a complete TAB?
□	□	□	Are all valves, flow meters, and temperature-pressure taps accessible?
□	□	□	Are all valves piped correctly?
□	□	□	Are all terminal unit coils installed correctly and accessible?
□	□	□	Are the terminal units piped correctly?
□	□	□	Are the piping systems free of debris?
□	□	□	Have the piping systems been cleaned and flushed?
□	□	□	Are all air vents properly installed?
□	□	□	Are vibration isolators properly installed and adjusted?
□	□	□	Are flexible connections installed properly?

Notes: This checklist is an example and shall be customized for each individual project.
N/A = Not Applicable to this project.

SECTION 23 09 00 - TEMPERATURE CONTROLS

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

B. Section 230910 (Sequence of Operation) is hereby made a part of this section.

PART 2 - SCOPE OF WORK

2.1 GENERAL

A. The control system shall provide direct digital control with a Windows-based user interface. Third party viewing software is not acceptable. The manufacturer and/or his authorized representative shall be responsible for all work under this section of the specifications. Only pre-approved manufacturers and contractors will be allowed and shall be as follows (no substitutions):

Manufacturers	Northern Nevada Contractors	Telephone
Alerton Controls	Cerris Systems	(775) 826-8998

B. Furnish and install an energy management control system (EMCS) and direct digital control (DDC) system complete with computer terminal (when specified), modem, surge suppressor, operating software, and training. Install the temperature control system software (most current edition) on the existing computer at the using agency's office and on the computer at the project site (when an on-site computer is specified). When third party software is necessary to allow for control system programming and/or editing of graphic displays that software (most current edition) shall also be provided on each of the aforementioned computers.

C. There shall be no annual maintenance or licensing fees of any kind required to be paid by the Owner at any time during the ongoing use of the installed system and software. Licenses shall be issued and authorized as directed by the Owner. Licenses shall be issued such that they can be modified by the Owner without the permission of the contractor and/or local system integrator. Specific license wording and format shall be provided as part of the contractor's submittals.

D. On any project that involves removal of existing controls, the Owner shall be given an opportunity to identify any control devices that they would like to have turned over to them for potential future use.

E. Alerton Controls System

1. The Alerton Controls System shall be configured with multiple Ethernet connections to allow for remote network access and for direct connection of multiple computers via local area network. The Alerton Controls system shall utilize 'Compass' web-based graphic interface software (most current version). Communication with equipment controllers shall be via BACnet IP Ethernet backbone at 100.0 Mbps minimum speed. Controllers for central plant equipment and/or air handling units shall be Alerton ACM series with AXM expansion I/O modules or Alerton VIP series equipment controllers. All equipment controllers shall be furnished with integral hand-off-auto switches. Communication between equipment controllers and application specific controllers (Alerton VLC series) shall be via BACnet MS/TP network at 76.8k minimum speed.

2.2 SPARE CONTROLLER CAPACITY

A. All controllers for central plant equipment and air handling units (except application-specific controllers for unitary equipment) shall be furnished with a minimum of 10 percent spare capacity to allow for addition of both analog and digital inputs and outputs.

2.3 SUBMITTALS AND AS-BUILT DOCUMENTATION

A. The written control sequences, initial setpoints, dead-bands, and the graphic displays shall all be reviewed and confirmed with the Owner and the Engineer prior to preparing and forwarding the finalized submittals.

B. The submittals shall include complete written control sequences for each item of equipment requiring control. The sequences shall include all setpoints, dead-bands, etc. required for successful operation of the specified equipment. The submitted sequences shall include all necessary sequencing details, whether or not those details are furnished as part of the mechanical engineer's written control sequences (such details are commonly excluded from the Engineer's written control sequences) and all work associated with developing and incorporating those details shall be provided by the Temperature Controls Contractor at no additional cost to the Owner.

C. The Temperature Control Contractor shall prepare and submit a complete listing of BACnet points that are to be set up as trended and stored historical data. The list shall be broken down to include each system and/or item of equipment and shall be reviewed with the Owner and the Engineer for approval prior to setting up the trending in the temperature control system. The BACnet trend log names shall also be provided for approval.

D. After all temperature control sequences have been finalized and have been approved by the Owner and the Engineer (and after the HVAC systems commissioning process has been completed) the Contractor shall provide as-built documentation which shall include both an electronic copy of the finalized programming and a hard copy of the finalized programming (programming flow charts or line code as may be applicable) and written control sequences.

2.4 TRAINING

A. Upon completion of the commissioning process, the Temperature Controls Contractor shall instruct the Owner's designated personnel on the operation of all control system software features, shall provide a complete explanation of the control sequence for each item of equipment, and shall provide instructions on the operation and maintenance of all control devices. Training time shall be a minimum of 8 total hours (consisting of 2 separate 4 hour sessions).

2.5 WARRANTY PERIOD SERVICES

A. The Contractor shall provide full service for the temperature control system for a period of one year after the date of substantial completion. Service shall include, as a minimum, calibration of all sensors and other control devices, adjustments to setpoints, and modifications to control sequences or programming as required/desired to fine-tune and/or finalize all control sequences.

B. The Contractor shall provide a scheduled monitoring and reporting service for the duration of the one year warranty period. Monitoring shall be conducted via the remote control system interface (via modem or network connection) and the associated report shall be issued via email the same day that the monitoring is conducted. Monitoring shall be conducted on a weekly basis, preferably on either Monday or Tuesday. Reports shall include a specific listing of all alarms, all equipment failures, any noted operational problems or irregularities, and a set of screen prints.

2.6 SOFTWARE AND PROGRAMMING REQUIREMENTS

A. Provide a security/password system with two passwords (username and password). The security/password system shall allow access based on user security level as follows:

Level 1 Viewing only
Level 2 Room temperature and occupancy schedule adjustment
Level 3 Adjustment of all setpoints
Level 4 Full access to all setpoints and programming

B. The Temperature Controls Contractor shall program the applicable holidays into the EMCS software for the five years following the date of the installation.

C. Equipment Schedules: Schedules shall be coordinated with the Owner. A separate or combined occupied/unoccupied schedule shall be provided for each air handling unit, fan coil unit, exhaust fan, and/or other individual air handling system as designated by the Owner.

2.7 GRAPHIC DISPLAYS

A. All temperature setpoints and all other setpoints identified as adjustable in the written control sequence shall be adjustable from the appropriate graphic display(s). Setpoints listed in the contract documents are for initial set-up and trial of system operations. Control system shop drawings shall utilize the same (or similar) written sequences with all setpoints, throttling ranges, and differentials identified. As-built drawings shall include this same information with final setpoints resulting from startup, testing, and adjustment.

B. Monitored points and alarms for each system shall be shown on the displays with full color graphics and real-time data as listed below. Where indicated, graphic displays shall be dynamic (animated). All graphic displays shall be submitted to the Owner and the Engineer for review and modification as directed.

C. All temperatures shall be displayed with zero decimal places.

D. All valve and damper positions shall be displayed as percent open and shall be displayed with zero decimal places.

E. All setpoints which are identified as ‘adjustable’ in the written control sequences shall be adjustable via the associated graphic displays (including deadband between room setpoints).

F. All occupied mode and unoccupied mode room temperature setpoints shall have an adjustable deadband (adjustable from the associated graphic display).

G. All displays specified to be dynamic shall depict motion (as a minimum, dynamic displays shall include chiller compressors, boiler burners, rotating fan wheels, and rotating pump impellers).

H. All setpoints adjustable from the graphic displays shall be programmed with the deadband on one side of the setpoint (not split evenly across the setpoint) unless otherwise specified.

I. All outputs shall be programmed with the capability for the user to override the controlled commands/positions via the associated graphic display (this requirement applies to all equipment, valves, dampers, fans, pumps, etc.).

J. Alarm data fields shall be displayed with a red text when an alarm condition exists.

K. A summary table shall be provided in the graphic screens to display the current status of each fire-smoke damper. The summary data shall also include the approximate location of each fire-smoke damper.

L. A set of zone temperature summary screens shall indicate the current room temperature setpoint and current room temperature for each zone. A separate global setpoint and deadband shall be assigned to all zones associated with each air handling unit. The zone summary screens shall also include additional information for each zone such as the remote setpoint and deadband, discharge air temperature, valve position, fan command, fan status, deadband setpoint(s), etc. Summary screen format, function, and required display data shall be coordinated with the Owner prior to developing the graphic displays.

M. Each zone shall be capable of being set to any of three setpoints (depending on which setpoint is selected). The three available setpoints shall be the global setpoint (a single setpoint for all associated zones), the remote setpoint (a separate individually adjustable setpoint for each zone), and the local setpoint (adjustable at the room sensor by utilizing a slide or dial type control on the room sensor). The local setpoint adjustment range shall be programmed to allow adjustment only between a fixed temperature range (typically between 73ºF and 75ºF - range to be confirmed with the Owner prior to programming).

N. Each variable frequency drive shall be programmed to display command, status (via current sensor), input speed, output speed, and alarm/failure status (via alarm contacts at each vfd).

O. Floor Plan(s): Provide a display showing the building floor plan(s) with all space temperature sensors including identification of the associated terminal unit or fan coil unit number. Specifically identify each thermal zone on the associated floor plan (AutoCAD file with thermal zone borders can be obtained from the mechanical engineer at no cost to the Contractor).

P. The current room temperature status shall be indicated utilizing custom thermal geometry outlines around each thermal zone with dynamic color and opacity based on the current zone temperature.

Q. The finalized sequence of operation shall be inserted into the graphics for viewing as a pdf file.

2.8 SPECIALTY CONTROL DEVICES AND REQUIREMENTS

A. Outdoor temperature sensor (dry bulb only) shall be Mamac Systems Model TE-213-F with solar radiation and precipitation shield, Dwyer Model TE-RND with solar radiation and precipitation shield, or approved equal.

B. Current sensors for fan and pump motors less than one horsepower shall be split core digital output type and shall have an adjustable setpoint capability.

C. Duct temperature sensor probes shall have a minimum length of 6 inches and shall be selected with longer lengths when required to ensure accurate temperature readings and to avoid dead air spaces.

D. Averaging sensors and freeze sensors shall be a minimum length of 12 feet. Longer lengths and/or multiple sensors shall be provided as required to ensure adequate coverage of the entire surface of each coil. Sensors shall be sized to provide complete coil coverage based on the requirements listed herein. Averaging and freeze sensor capillaries shall be installed in a serpentine arrangement with coverage extending to within 6” of each coil perimeter edge (top, bottom, and side edges) and shall be installed such that there is no more than 12” between horizontal passes. Averaging sensors shall provide for averaging of the entire length of the capillary element rather than an average of individual sensing locations.

E. Modulating control valves for typical heating and cooling coil applications shall be Belimo characterized control valves, B200S Series (2-way) or Belimo B300S Series (3-way) as indicated on the drawings, with Belimo LRX24 actuators. Control valves for HVAC applications shall be chrome plated brass body with stainless steel ball and stem. All actuators shall include a clutch to allow manual rotation of the valve. Actuators shall be spring return type when indicated on the drawings. Modulating control valves for pipe sizes 2-1/2” and larger shall be flanged body type. Modulating control valves shall be selected for a Cv that is adequately greater than the associated coil pressure drop (see equipment schedules on drawings for coil pressure drops).

F. Carbon Dioxide (CO_2) sensors for indoor applications shall be Vaisala GMW90 series for wall mount applications, Model GMD110 for duct mount applications, or approved equal. There shall be no value displayed on the wall mount sensor (only displayed on the control system remote graphic interface).

G. Carbon Dioxide (CO_2) sensors for outdoor wall mount applications shall be Vaisala GMP340 series, or approved equal. There shall be no value displayed on the room sensor (only displayed on the control system remote graphic interface).

H. Air filter differential pressure sensors shall be Dwyer Model MS2-X102, or approved equal. Dip switches for pre-filters shall be set for a 0 to 1” w.c. range, and dip switches for final filters shall be set for a 0 to 2” w.c. range.

I. Differential pressure sensors for dry applications shall be Dwyer 650 Series, Veris Industries Model PX, Senva Model P4, or approved equal. Verify desired/required sensing range prior to submitting and/or ordering. Sensor tubing connections shall be fitted with brass test tees for use by the test and balance contractor for verification/calibration.

J. Differential pressure sensors for wet applications shall be Veris Industries PWRLX series, or approved equal. Verify the desired/required sensing range prior to submitting and/or ordering. Sensor tubing connections shall be fitted with brass test tees for use by the test and balance contractor for verification/calibration.

K. Air flow measuring stations shall be thermal dispersion type, Ebtron Gold Series Model GTx116, Ruskin Airflow IQ Series Model TDP05K, or approved equal. Sensor density and location shall be configured in strict conformance with the manufacturer's written installation instructions. Duct mounted air flow measuring stations shall be installed with a minimum of 12" of straight duct upstream of the sensor and with a minimum of 6" of straight duct downstream of the sensor. Duct sizing shall ensure a minimum velocity of 250 fpm.

L. Building static pressure sensors shall have a control range of ± .10" w.c. Sensor shall be Mamac Model PR-275-R2, Dwyer MSX series, Veris Industries Model PX-01-F (fast response), Setra Model 264-0R1WB, or approved equal, and shall be furnished with indoor and outdoor reference probes.

1. Outdoor static pressure probe shall be constructed of anodized aluminum and shall be capable of sensing static pressure to within 2% accuracy when subject to radial wind velocities of up to 80 mph with an approach angle of up to 30 degrees from horizontal. Outdoor probe shall be 'Static Outside Air Probe' by Air Monitor Corporation, Model PE-8000 Outside Air Probe by Paragon Controls, or approved equal.
2. Indoor static pressure probe(s) shall be suitable for flush mounting, shall be constructed of 10 gauge brushed aluminum, and shall be capable of sensing static pressure to within 1% accuracy when subject to air velocities of up to 1,000 fpm. Indoor static pressure probes shall be 'Shielded Static Air Probe No. 3' by Air Monitor Corporation, Paragon PE-7000 Indoor Static Pressure Probe, or approved equal.
3. Provide a surge dampener for each indoor static pressure probe/sensor. Surge dampeners shall be Schneider Electric Model 21-153, Kele & Associates Model SD-01, or approved equal. Interconnecting tubing between sensor and indoor/outdoor probes shall be 3/8" diameter braid-reinforced pvc or polyethylene tubing. Copper tubing is required in any case where the tubing is installed in a return air plenum.

2.9 MISCELLANEOUS REQUIREMENTS

A. All control devices shall be installed in reasonably accessible locations. Control devices that may require occasional calibration or adjustment shall be given special consideration with regard to being installed in a reasonably accessible location.

B. Room temperature sensors shall be programmable touchscreen type and shall be provided with an override feature and setpoint adjustment with the ability to be limited or locked out via the operator workstation.

C. Room temperature sensors shall be labeled with the corresponding terminal unit or fan coil unit number. Labels shall be self-adhesive with black lettering (1/8" height lettering).

D. Room temperature sensors in laboratory areas shall be sealed at the wall penetration behind the sensor to prevent air migration into the sensor from adjacent areas (due to the negative pressure of labs as compared to adjoining spaces).

E. Equipment specified to include a BACnet interface shall be provided with a terminal strip to allow remote control of the equipment via the direct digital control system (verify this requirement on the equipment schedules and/or in the equipment specifications).

F. When an air handling unit is depicted as including a temperature sensor at the inlet and at the outlet of the chilled water and/or heating water coil those sensors shall be 'paired thermistors'.

G. Sensor wells installed in a potable water system shall be stainless steel.

H. All control dampers in stainless steel ductwork shall be constructed of stainless steel and shall have flanged connections.

I. An as-built control diagram shall be laminated and secured inside of each temperature control panel prior to commencement of the final on-site mechanical systems commissioning sessions.

J. Trend logs shall be coordinated with the Owner and shall include as a minimum all identified temperature, pressure, gpm, cfm, percentage, status, and alarm data that is requested.

K. All low voltage wiring (whether plenum rated or not) shall be installed in raceways with the following conditions, clarifications, and exceptions.
   1. Raceways shall be as defined in the National Electrical Code and open cable trays shall not be construed as meeting the definition of a raceway.
   2. Low voltage wiring for temperature controls and energy management systems may be routed utilizing open cable trays above accessible ceilings. Low voltage wiring for temperature controls and energy management systems may also be installed utilizing appropriately spaced and neatly routed j-supports above accessible ceilings. Low voltage wiring routed in walls or at roof penetrations shall be installed in conduit.
   3. Where open cable trays are utilized above accessible ceilings the following conditions apply.
      a. Low voltage wiring routed in open cable trays shall be plenum-rated (whether or not the ceiling space is utilized as a return air plenum).
      b. Low voltage wiring concealed in walls, floors, and above inaccessible ceilings shall be routed in raceways.
      c. Low voltage wiring routed between conduit stubs and cable trays shall be secured with appropriately spaced j-supports.

END OF SECTION

SECTION 23 09 10 - SEQUENCE OF OPERATION

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

B. Section 230900 (Temperature Controls) is hereby made a part of this section.

1.2 SEQUENCE OF OPERATION

AIR HANDLING UNIT AH-1

Occupied Mode

The air handling unit supply fan and associated exhaust fan shall be enabled continuously at the occupied time (unless enabled earlier utilizing the optimum start program). OA damper shall be fully open. RA damper shall be fully closed. The heating water control valve shall be modulated to maintain the supply air temperature setpoint (90ºF, adjustable). Supply air temperature shall reset to maintain space temperature. The heating valve programming shall include logic that prevents the leaving air temperature from being more than 15°F above the current room temperature setpoint, as recommended by ASHRAE Standard 90.1 Section 6.5.2.1.1. The 15°F limit can be exceeded during transition between unoccupied mode to occupied mode.

Unoccupied Mode

The air handling unit fan is disabled, associated exhaust fan is disabled, the heating water control valves are closed, the outside air damper is closed, and the return air damper is open.

Unoccupied Heating Mode

The air handling unit supply fan is enabled, the outside air dampers are fully closed, the return air damper is fully open, and the associated exhaust fan is disabled. The air handling unit supply air temperature is reset to (70ºF, adjustable). The transition from the unoccupied mode supply air temperature setpoint of 70ºF to the occupied mode setpoint of 55ºF shall be implemented gradually over a 10 minute time period (to avoid the potential of causing a freeze safety condition during cold weather extremes).

Unoccupied Override Mode

Whenever the zone sensor override button is pressed during the unoccupied time period, the air handling unit shall be enabled and controlled in the normal occupied mode for a period of (2 hours, adjustable).

Optimum Start Mode (Morning Warm-Up)

During morning warm-up and/or morning cool-down modes the air handling unit shall operate in accordance with the appropriate unoccupied mode sequence (Unoccupied Heating Mode) and shall be enabled at such a time that the occupied mode setpoint is reached at the occupied time.

Safeties

Whenever the temperature at the averaging sensor (located downstream of the heating coil) falls below setpoint (60ºF, adjustable) the outside air damper shall close, the return air damper shall open, the heating water valve shall be fully open, and an alarm condition shall be indicated. Once the outside air temperature rises to 40°F the air handling unit shall be released to operate in the normal mode.

Whenever the manual reset freeze thermostat (located downstream of the heating coil) falls below setpoint (approximately 35ºF) the supply fan shall be disabled, the outside air damper shall close, the return air damper shall open, the heating water valve shall be fully open, and an alarm condition shall be indicated.

The supply fan low static pressure sensor/control (manual reset) shall disable the fan whenever the duct static pressure exceeds setpoint (-3.5" w.c.).

The exhaust fan (EF-1) high static pressure sensor/control (manual reset) shall disable the fan whenever the duct static pressure exceeds setpoint (3.5" w.c.).

The filter pressure drop sensor(s) shall indicate an alarm condition whenever the filter pressure drop exceeds setpoint (1.0" w.c., adjustable).

The duct-mounted smoke detector shall disable the fans and dampers whenever smoke is detected.

AIR HANDLING UNITS AH-2 and AH-5

Occupied Heating Mode

The air handling unit supply fan and associated exhaust fan(s) shall be enabled continuously at the occupied time (unless enabled earlier utilizing the optimum start program). The OA damper, EA damper, and RA damper shall open to maintain min OA cfm. The heating water control valve shall be modulated to maintain the supply air temperature setpoint (85ºF, adjustable). Supply air temperature shall reset to maintain space temperature. The heating valve programming shall include logic that prevents the leaving air temperature from being more than 15°F above the current room temperature setpoint, as recommended by ASHRAE Standard 90.1 Section 6.5.2.1.1. The 15°F limit can be exceeded during transition between unoccupied mode to occupied mode.

Occupied Cooling Mode

The air handling unit supply fan and associated exhaust fan(s) shall be enabled continuously at the occupied time (unless enabled earlier utilizing the optimum start program). The OA damper, EA damper, and RA damper shall open to maintain min OA cfm. The associated condensing unit shall be modulated to maintain the supply air temperature setpoint (55ºF, adjustable). Supply air temperature shall reset to maintain space temperature.

Economizer Mode

The economizer mode shall be enabled whenever the outside air temperature is 2°F below the return air temperature (with a 2°F deadband, disabled when outside air temperature equals the return air temperature). During economizer mode there shall be an additional control parameter that manages the outside air and return air damper positions such that the mixed air temperature does not fall below the mixed air temperature low limit setpoint (50ºF, adjustable) at any time.

Whenever the air handling unit is operating in economizer mode the economizer dampers shall be fully open before the associated condensing unit begins to operate.

Whenever the outside air temperature is below 30°F, the economizer dampers shall be limited such that it does not exceed (50% open, adjustable), and the condensing unit shall be off.

Demand Control Ventilation Mode (AHU-5 only)

In normal operation, outside air damper shall be fully closed and return air damper shall be fully open. The outside air damper shall fully open and return air damper shall fully close to enter demand control ventilation mode when CO2 level reaches (1200 ppm, adjustable) with a deadband (600 ppm, adjustable). When CO2 level reaches (600 ppm, adjustable), demand control ventilation mode shall release and unit shall return to normal operation.

Unoccupied Mode

The air handling unit fan and associated exhaust fan(s) is disabled, the control valves are closed, associated condensing unit is disabled, the outside air damper is closed, the exhaust damper is closed, and the return air damper is open.

Unoccupied Heating Mode

The air handling unit supply fan is enabled, the outside air dampers are fully closed, the return air damper is fully open, and the associated exhaust fan(s) is disabled. The air handling unit supply air temperature is controlled to the occupied mode setpoint (85ºF, adjustable).

Unoccupied Cooling Mode

The air handling unit supply fan is enabled, the outside air dampers are fully closed, the return air damper is fully open, and the associated exhaust fans are disabled. The air handling unit supply air temperature is controlled to the occupied mode setpoint (55ºF, adjustable).

Unoccupied Override Mode

Whenever the room sensor override button is pressed during the unoccupied time period the air handling unit shall be enabled and controlled in the normal occupied mode for a period of (2 hours, adjustable).

Optimum Start Mode (Morning Warm-Up and Morning Cool-Down Modes)
During morning warm-up and/or morning cool-down modes the air handling unit shall operate in accordance with the appropriate unoccupied mode sequence (Unoccupied Heating Mode or Unoccupied Cooling Mode) and shall be enabled at such a time that the occupied mode setpoint is met at the occupied time.

Safeties
Whenever the temperature at the averaging sensor (located downstream of the heating coil) falls below setpoint (40ºF, adjustable) the associated exhaust fans shall be disabled, outside air and exhaust dampers shall close, the return air damper shall open, the heating water valve shall be fully open, and an alarm condition shall be indicated. Once the outside air temperature rises to 40°F the air handling unit shall be released to operate in the normal mode.

Whenever the manual reset freeze thermostat (located downstream of the heating coil) falls below setpoint (approximately 35ºF) the supply fan shall be disabled, the associated exhaust fan shall be disabled, the outside air and exhaust dampers shall close, the return air damper shall open, the heating water valve shall be fully open, and an alarm condition shall be indicated.

The supply fan low static pressure sensor/control (manual reset) shall disable the fan whenever the duct static pressure exceeds setpoint (-3.5" w.c.).

The exhaust fan high static pressure sensor/control (manual reset) shall disable the fan whenever the duct static pressure exceeds setpoint (3.5" w.c.).

The filter pressure drop sensor(s) shall indicate an alarm condition whenever the filter pressure drop exceeds setpoint (1.0" w.c., adjustable).

The duct-mounted smoke detector shall disable the fans and dampers whenever smoke is detected.

The refrigerant leak sensor shall detect a leak when 25% or more of the lower flammability limit (LFL) of the refrigerant is detected (R454B LFL = 18.5 lbs/1000ft^3). Within 15 seconds of detection of a refrigerant leak, supply fan and associated exhaust fans shall be enabled, associated condensing unit shall be deenergized, and an alarm condition shall be enabled. Refrigerant mitigation procedures shall be maintained for a minimum of 5 minutes after the refrigerant leak sensor no longer detects a refrigerant leak.

AIR HANDLING UNIT AH-3

Occupied Mode
The air handling unit supply fan and associated exhaust fan(s) shall be enabled continuously. The heat recovery OA damper and heat recovery EA damper shall open fully. Non-heat recovery OA damper, EA damper, and RA damper shall remain closed.
The heat recovery pump shall be enabled whenever OA temperature falls below the set pool temperature plus 3°F (adjustable), and the exhaust temperature is greater than OA temperature. The heating water control valve shall be modulated to maintain the supply air temperature 3ºF (adjustable) higher than the set pool temperature.
The supply fan speed shall modulate between the minimum CFM (5,000, adjustable) and maximum CFM (12,000, adjustable) as measured by the intake flow station to maintain the relative humidity (RH) setpoint (55% RH, adjustable). The associated exhaust fan(s) speed shall modulate to maintain an offset of (+600 cfm, adjustable) as measured by the exhaust air flow station.
The non-heat recovery OA damper and EA damper shall modulate open to maintain a maximum of 5,000 CFM across the heat recovery coils as measured by the intake and exhaust air flow station.
Whenever the temperature at the mixed air sensor falls below the setpoint of (50ºF, adjustable), the non-heat recovery OA and EA dampers shall be closed, and the supply fan speed shall be limited to the minimum CFM Setpoint as measured at the intake flow station.
Safeties
Whenever the temperature at the mixed air sensor falls below the setpoint of (45ºF, adjustable), the heat recovery OA, EA and RA dampers shall modulate closed to maintain a minimum mixed air temperature of (45ºF, adjustable).

Whenever the heating water valve is open more than 75% and the temperature at the supply air sensor falls below the setpoint of (40ºF, adjustable), all OA and EA dampers shall close, the return air damper shall open, the heating water valve shall be fully open, and an alarm condition shall be indicated. Once the outside air temperature rises to 40°F the air handling unit shall be released to operate in the normal mode.

Whenever the manual reset freeze thermostat (located downstream of the heat recovery coil) falls below setpoint (approximately 20ºF) the OA, and EA dampers shall close, the RA dampers shall open, and heat recovery pump shall start.

Whenever the manual reset freeze thermostat (located downstream of the heating coil) falls below setpoint (approximately 35ºF) the supply fan shall be disabled, the associated exhaust fan shall be disabled, all outside air and exhaust dampers shall close, the return air damper shall open, the heating water valve shall be fully open, and an alarm condition shall be indicated.

The supply fan low static pressure sensor/control (manual reset) shall disable the fans whenever the duct static pressure exceeds setpoint (-3.5" w.c.).

The exhaust fan high static pressure sensor/control (manual reset) shall disable the fans whenever the duct static pressure exceeds setpoint (3.5" w.c.).

The filter pressure drop sensor(s) shall indicate an alarm condition whenever the filter pressure drop exceeds setpoint (1.0" w.c., adjustable).

The duct-mounted smoke detector shall disable the fans and dampers whenever smoke is detected.

AIR HANDLING UNIT AH-4

Occupied Mode

The air handling unit supply fan and associated exhaust fan(s) shall be enabled continuously at the occupied time (unless enabled earlier utilizing the optimum start program).

The heating water control valve and associated condensing unit shall be modulated to maintain the supply air temperature setpoint (55ºF, adjustable). Supply air temperature shall reset to maintain space temperature during periods of high space temperature as needed.

Economizer Mode

The economizer mode shall be enabled whenever the outside air temperature is 2°F below the return air temperature (with a 2°F deadband, disabled when outside air temperature equals the return air temperature). During economizer mode there shall be an additional control parameter that manages the outside air and return air damper positions such that the mixed air temperature does not fall below the mixed air temperature low limit setpoint (50ºF, adjustable) at any time.

Whenever the air handling unit is operating in economizer mode the economizer dampers shall be fully open before the associated condensing unit begins to operate.

Whenever the outside air temperature is below 30°F, the economizer dampers shall be limited such that it does not exceed (50% open, adjustable), and the condensing unit shall be off.

Unoccupied Mode

The air handling unit fan and associated exhaust fan(s) is disabled, the control valves are closed, associated condensing unit is disabled, the outside air damper is closed, the exhaust damper is closed, and the return air damper is open.

Unoccupied Heating Mode

The air handling unit supply fan is enabled, the outside air dampers are fully closed, the return air damper is fully open, and the associated exhaust fan(s) is disabled. The air handling unit supply air temperature is reset to (70ºF, adjustable). The transition from the unoccupied mode supply air temperature setpoint of 70ºF to the occupied mode setpoint of (55ºF, adjustable) shall be implemented gradually over a 10 minute time period (to avoid the potential of causing a freeze safety condition during cold weather extremes).

Unoccupied Cooling Mode

The air handling unit supply fan is enabled, the outside air dampers are fully closed, the return air damper is fully open, and the associated exhaust fan(s) is disabled. The air handling unit supply air temperature is controlled to the occupied mode setpoint (55ºF, adjustable).

Unoccupied Override Mode
Whenever the room sensor override button is pressed during the unoccupied time period the air handling unit shall be enabled and controlled in the normal occupied mode for a period of (2 hours, adjustable).

Optimum Start Mode (Morning Warm-Up and Morning Cool-Down Modes)
During morning warm-up and/or morning cool-down modes the air handling unit shall operate in accordance with the appropriate unoccupied mode sequence (Unoccupied Heating Mode or Unoccupied Cooling Mode) and shall be enabled at such a time that the occupied mode setpoint is met at the occupied time.

Safeties
Whenever the temperature at the averaging sensor (located downstream of the heating coil) falls below setpoint (40ºF, adjustable) the associated exhaust fans shall be disabled, outside air and exhaust dampers shall close, the return air damper shall open, the heating water valve shall be fully open, and an alarm condition shall be indicated. Once the outside air temperature rises to 40°F the air handling unit shall be released to operate in the normal mode.

Whenever the manual reset freeze thermostat (located downstream of the heating coil) falls below setpoint (approximately 35ºF) the supply fan shall be disabled, the associated exhaust fan shall be disabled, the outside air and exhaust dampers shall close, the return air damper shall open, the heating water valve shall be fully open, and an alarm condition shall be indicated.

The supply fan low static pressure sensor/control (manual reset) shall disable the fans whenever the duct static pressure exceeds setpoint (-3.5" w.c.).

The exhaust fan high static pressure sensor/control (manual reset) shall disable the fan whenever the duct static pressure exceeds setpoint (3.5" w.c.).

The filter pressure drop sensor(s) shall indicate an alarm condition whenever the filter pressure drop exceeds setpoint (1.0" w.c., adjustable).

The duct-mounted smoke detector shall disable the fans and dampers whenever smoke is detected.

The refrigerant leak sensor shall detect a leak when 25% or more of the lower flammability limit (LFL) of the used refrigerant is detected (R454B LFL = 18.5 lbs/1000ft^3). Within 15 seconds of detection of a refrigerant leak, supply fan and associated exhaust fans shall be enabled, associated condensing unit shall be deenergized, and an alarm condition shall be enabled. Refrigerant mitigation procedures shall be maintained for a minimum of 5 minutes after the refrigerant leak sensor no longer detects a refrigerant leak.

Heating Coils
Occupied Mode
The heating water control valve shall be modulated as required to maintain the current zone temperature setpoint (initial cooling setpoint @ 75°F, with a 5°F deadband, heating on @ 70°F). The heating valve programming shall include logic that prevents the leaving air temperature from being more than 15°F above the current zone temperature setpoint, as recommended by ASHRAE Standard 90.1 Section 6.5.2.1.1. The 15°F limit can be exceeded during transition between unoccupied mode to occupied mode.

Unoccupied Heating Mode
Whenever any zone temperature falls below the unoccupied mode heating setpoint (55°F setpoint with a 5°F differential, off at 60°F) the air handling unit shall be enabled in unoccupied heating mode.The unoccupied heating mode shall be terminated when all zones have reached the top end of the unoccupied heating setpoint differential (60°F).

Unoccupied Cooling Mode
Whenever any zone temperature rises above the unoccupied mode cooling setpoint (85°F setpoint with a 5°F differential, off at 80°F) the air handling unit shall be enabled in unoccupied cooling mode. The unoccupied cooling mode shall be terminated when all zones have reached the bottom end of the unoccupied cooling setpoint differential (80°F).

Unoccupied Override Mode

Whenever one of the zone sensor override buttons is pressed during the unoccupied time period the air handling unit shall be enabled and controlled in the normal occupied mode for a period of 2 hours, adjustable). The heating coil that initiated the override (and any others that are subsequently overridden) shall control to the *occupied* mode room temperature setpoint. All other heating coils associated with that air handling unit shall control to the *unoccupied* mode zone temperature setpoint.

EXHAUST FANS

EF-1 enabled whenever AHU-1 is enabled.
EF-2 enabled whenever AHU-2 is enabled.
EF-3 enabled whenever AHU-3 is enabled.
EF-4 enabled whenever AHU-4 is enabled.
EF-5 enabled whenever AHU-5 is enabled.
EF-6 enabled whenever AHU-2 is enabled.
EF-7 enabled whenever AHU-4 is enabled.
EF-8 enabled in occupied mode.

END OF SECTION

SECTION 23 09 20 - VARIABLE FREQUENCY DRIVES

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

1.2 GENERAL

A. This specification is for complete variable frequency drives consisting of a pulse width modulated (PWM) inverter designed for use with NEMA MG Part 31 inverter rated motors.

B. All VFDs installed on the project shall be from the same manufacturer.

C. The VFD manufacturer shall supply UL508/IEC Standard 61800-5 labeled drives with the options specified. To ensure continued technical and logistical support, VFDs manufactured by a third party or brand labeled will not be acceptable.

1.3 QUALITY ASSURANCE

A. Referenced Standards and Guidelines
   1. Underwriters Laboratory 508 (A) or (C) as appropriate for Industrial Control Panels.
   2. SEMI F47-0706 for voltage sag immunity
   3. EN/IEC/CE mark 61800.3-EMC, EMI &RFI compliance.
   4. The most current adopted edition of the International Building Code (IBC) referencing ASC 7-05 and ICC AC-156.
   5. International Electrotechnical Commission 60721-3c1, 2 & 3 conformed coating on PCBs.
   6. Office of Statewide Health Planning and Development (OSHPD) approval as required.

B. Qualifications
   1. Drives shall be UL labeled as a complete assembly. The base VFD shall be UL listed for 100 kA SCCR when installed in accordance with the manufacturer's guidelines.
   2. VFD assembly shall be seismically certified and labeled in accordance with latest IBC.
   3. Base VFD shall have CE mark conforming to EN 61800-3 for 1st Environment level (C2).
   4. The base drive shall be SEMI-F47 certified. The drive must tolerate voltage sags from 35-50%.
   5. VFD enclosures from VFD manufacturer shall be UL rated for proper environment: 1, 12, or 3R, 4, or 4X as indicated on the drawings or herein. Cabinets shall be correctly sized for airflow and heat dissipation with an interlocked handle. Outdoor enclosures shall be constructed of steel (or non-rusting material as appropriate for the installation location) and shall include thermostatically controlled cooling fans and heaters.
   6. Factory authorized start up and owner training should be provided locally upon request. A toll free 24/365 technical support line connected to factory support personnel located in the US shall be available.

C. Acceptable Manufacturers: Subject to compliance with requirements, manufacturers offering variable frequency drives which may be incorporated in the work include the following:

   ABB (ACH580 Series with electrolytic capacitors)
   Danfoss (FC102 Series with electrolytic capacitors)

1.4 WARRANTY

A. The variable frequency drive warranty shall be for 2 years from the date of start-up and shall include all parts, labor, travel time, and expenses.

1.5 SUBMITTALS

A. Submittals shall include the following information.
   1. Outline dimensions, conduit entry locations and weights, field connection and power wiring diagrams.
   2. OSHPD preapproval, seismic certification and installation requirements where applicable.
   3. Complete technical product description with complete list of options provided. Any portions of this specification not met must be clearly indicated or the Supplier and Contractor shall be liable to provide all additional components required to meet this entire specification.

PART 2 - PRODUCTS

2.1 VARIABLE FREQUENCY DRIVES

A. Each VFD shall provide full rated output between +10% and -15% of nominal voltage. The VFD shall continue to operate without faulting with surges between +30% to -35% of nominal voltage. VFDs shall be capable of continuous full load operation under the following environmental operating conditions.
   1. 5 to 104°F ambient temperature. Operation to 122°F shall be acceptable with a 10% reduction from VFD full load current.
   2. Altitude from 0 to 3300 feet above sea level. Operation to 6600 feet shall be allowed with a 10% reduction from VFD full load current.
   3. Humidity less than 95%, non-condensing.

B. VFDs shall have the following standard features.
   1. VFDs shall be constructed with electrolytic capacitors and dual DC chokes (no exceptions).
   2. VFDs shall incorporate an integral electrical disconnect with auxiliary contacts. The short circuit current rating (SSCR) of the integral disconnect switch shall match or exceed the SSCR of the source panel or distribution board. Coordinate with Division 26 for results of Specification Section 26 05 73.13 (Short-Circuit Studies) prior to ordering any VFD.
   3. All circuit boards shall be coated to protect against corrosion to meet IEC 60721-3c2.
   4. VFDs shall all have the same HMI/keypad with time clock built in. It shall be removable, capable of remote mounting, allow for uploading & downloading parameter settings, pre-programmed application macros to facilitate start-up have two user savable programs, it shall incorporate ‘bump-less transfer’ of speed reference when switching between ‘Hand’ and ‘Auto’ modes and have password protection.
   5. HMI/keypad to have Hand-Off-Auto modes, 2-4 Navigation keys, manual speed control, fault reset on it. Display shall be backlit, have a minimum of three lines, and messages shall use complete words (alphanumeric codes only are not acceptable.) Show load direction, speed, and reference or user set values in engineering units for submetering purposes (i.e., gph, kW, motor amps, frequency, speed, torque, etc.).
   6. The drive shall have the option to support a Bluetooth advanced control panel. The Bluetooth control panel shall be FCC and QDL (Qualified Design Listing) certified.
   7. VFDs shall include a coordinated AC transient surge protection system consisting of four metal oxide varistors (phase to phase & phase to ground), capacitor clamp, 1600 PIV Diode Bridge and chokes.
   8. VFDs shall have 3 to 5% impedance AC reactors or internal dual 5% DC chokes to reduce harmonics to the power line and as protection from AC line transients. VFDs with only one DC choke shall have OEM add AC UL 508 listed and approved line reactors.

9. VFDs shall automatically mitigate harmonics throughout the effective load range using Swinging chokes or other devices designed to lower harmonics when VFD is at partial loads. VFDs using thin wall, small DC bus or metallic type capacitors Must add active harmonic filters to prevent high frequency harmonics from corrupting the electrical system.
10. When Active Front End (Ultra Low Harmonic) drives are specified on the schedule, they must meet the following characteristics.
    a. An IGBT based active front end shall be used for mitigation of low frequency harmonics. An LCL filter shall be installed in front of the IGBTs to remove high frequency harmonics.
    b. Limit current distortion to 3% total harmonic current distortion at full load, at the lugs of the drive.
    c. The drive shall provide full motor nameplate voltage while operating the motor at nameplate RPM. The output IGBTs must be modulating and in control of the motor during this 100% speed/load operating condition. The specified 3% current distortion and 1.0 displacement power factor shall be achievable during this operating condition.
    d. The hardware structure of the front end shall boost the DC bus voltage by 10% during low line conditions.
11. VFDs shall be CE marked and meet Standard EN 61800-3-5 for the first environment restricted level (Category C2).
12. VFDs shall be CE marked and meet Standard EN 61800-3-5 for the first environment restricted level (Category C2).
13. VFDs shall be able to have a distance from the VFD to the motor of at least 250 feet at the maximum carrier frequency complying with the drive manufacturer’s installation, operating, and maintenance instructions, or provide a DV/DT filter for each VFD as necessary to protect the motors.
14. VFDs shall have a standardized control board, with all communications and I/O terminals on it, and standard building management system (BMS) communications protocols shall include Modbus RTU, Johnson Controls N2, and BACnet MS/TP. Diagnostic warning and fault information shall be transmittable over BMS, with remote fault reset when programmed. Communication options shall be available for Ethernet IP, BACnet IP, ControlNet, DeviceNet, EtherCAT, LonWorks, Modbus TCP, and Profibus.
15. VFDs shall have pass thru inputs and outputs. BMS can monitor/control VFD analog & digital I/O via communications independently of VFD functions or used for other devices/sensors.
16. VFDs shall have 250 ma of 24 VDC power for I/O and be capable of loop powering a transmitter.
17. Provide two programmable analog inputs of 0-10vdc or 4-20 ma.
18. Provide two programmable analog outputs of 0-20ma or 4-20 ma signals. Outputs proportionally programmable for: motor current, power, speed, torque, (kW) and other data.
19. Provide 6 programmable 24VDC digital inputs, able to operate normally or inverted.
20. Provide 3 programmable, Form-C relay outputs. Relay outputs shall be programmable on and off with time delay and adjustable hysteresis. Maximum switching current of 2 amps at 24 VDC, and 2 amps at 250 VAC; Maximum voltage of 250 VDC and 250 VAC; continuous RMS rating of 2 amps resistive load.
21. VFD heat-sink fans shall be variable speed or thermostatically control, and shall be replaceable without removing the VFD from the wall. Operation shall be based on the temperature and run command to the drive.
22. Drive Options: All optional features shall be UL listed by the VFD manufacturer as a complete assembly and shall carry a UL508 label.
23. Provide an option for non-powered programming via laptop and adapter.

24. When indicated on the drawings provide the optional Bluetooth Advanced Control Panel. The Bluetooth control panel shall be FCC and QDL (Qualified Design Listing) certified.
    a. A free app (iOS and Android) shall replicate the control panel on a mobile device or tablet. The control panel's programming and control functionality shall function on the device. Customizing text, such as AHU-1 end switch, shall be supported by the device's keyboard.
    b. Bluetooth connectivity shall allow uploading, downloading, and emailing of parameters.
    c. Bluetooth connectivity shall include two pairing modes: Always discoverable with a fixed passcode, and manual discovery with a uniquely generated passcode every pairing.

C. VFDs shall have the following programmable adjustments.
    1. Three programmable fully adjustable skip frequencies, from 0 to full speed.
    2. VFDs shall include a programmable time delay for start/stop with keypad indication time delay on.
    3. Two independent adjustable acceleration and deceleration ramps, with 1-1800 seconds adjustable time ramps.
    4. VFDs shall include a motor flux optimization circuit to automatically reduce applied motor voltage to motor to optimize energy consumption and reduce audible motor noise.
    5. VFDs shall provide a programmable loss-of-load (broken belt/coupling) option to signal the loss-of-load condition via a keypad warning, relay output, and/or over BMS.
    6. VFDs shall have 'Sleep' and 'Wake-Up' functions to control the VFD from the process feedback signal.
    7. VFDs shall have two PID controls built in for VFD or other uses. PID controllers shall have ability for 'two zone' control. PID setpoints shall be adjustable from the VFD keypad, analog inputs, or BMS.
    8. If input speed reference or remote communication is lost, the VFD shall be programmable to indicate a stop and display fault, run at a programmable preset speed, hold the VFD speed based on the last good reference received, or go to a backup control system wired to the VFD. The VFD shall also be capable to issuing a warning locally and via BMS.
    9. VFDs shall have programmable ability to automatically restart after overcurrent, over or under voltage, loss of input signal or protective trip as well as number of restarts and time between.
    10. VFDs shall be capable of starting into a coasting load (flying start). Forward or reverse up to full speed and accelerate or decelerate to setpoint without tripping or component damage.
    11. VFDs shall include a fireman's override input that when activated shall operate in one of two modes: 1-5 fixed digital speeds ranging from 500Hz to -500Hz, or Real Time Continuous Control aka analog speed control in fireman's override PID algorithm to automatically adjust motor speed based on override setpoint and feedback. This shall override all other inputs (analog/digital, communication, and all keypad commands), except customer defined safety run interlocks, and shall force the motor to run in one of the two modes. 'Override Mode' shall be displayed on the keypad. Upon removal of the override signal, the VFD shall resume normal operation, without the need to cycle the normal digital input run command. Also, shall be programmable with up to 5 speeds selected by inputs with an at speed indication and underload capability.

D. Micro VFDs shall have the following features and programmability.
   1. Microdrive's shall have HMI/keypad to have Hand-Off-Auto modes, manual speed control, fault reset on keypad, and the ability to program the VFD for all functions. Ability to save the VFD program is preferred.
   2. Microdrive's shall have the ability to run on single phase of power when derated 50%.
   3. Microdrive's shall have at least one analog input, and digital inputs and outputs built in when needed.
   4. Microdrive's when required shall have BMS communication protocols to include Modbus RTU; Johnson Controls N2, and BACnet MS/TP.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Installation shall be the responsibility of the Contractor. The Contractor shall install the drive in accordance with the recommendations of the VFD manufacturer as outlined in the VFD installation manual, NEC and local codes. The Contractor shall complete all wiring in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.

B. Power wiring shall be completed by the electrical contractor in accordance with NEC Section 430.122 wiring requirements based on the VFD input current.

C. For all VFD applications, the input and output cables to/from the VFD shall be run in separate metal conduits, or using shielded VFD cable. For multi-motor applications each VFD output shall have its own metal conduit or shielded VFD cable to/from the motor. Each motor shall have its own properly rated motor overload protection.

D. Input and output power wiring shall be segregated from low voltage analog, communication, control, and be UL listed for the appropriate voltage and be shielded cable. Installation shall be per the NEC and shall include adequate clearance between types.

3.2 STARTUP

A. Startup and checkout of each variable frequency drive shall be conducted by a factory trained service technician. An associated startup report shall be provided for each VFD.

3.3 PRODUCT SUPPORT

A. Factory trained application engineering and service personnel that are thoroughly familiar with the specified VFD products shall be locally available at the installation location. A toll free 24 hour/365 day technical support phone line connected to factory support personnel located in the United States shall be available.

B. Training by a factory authorized technician shall include installation, programming, and operation instruction for each VFD.

C. The VFD supplier shall stock standard drives and standard repair parts such that the Owner does not need to stock them.

END OF SECTION

SECTION 23 20 10 - SELF-SENSING HYDRONIC PUMPS

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC Systems) are hereby made a part of this section.

PART 2 - PRODUCTS

2.1 HYDRONIC PUMPS (SELF-SENSING TYPE)

A. General: Provide factory-tested self-sensing pumps, thoroughly cleaned, and painted with one coat of machinery enamel prior to shipment. Type, size, and capacity of each pump shall be as listed in the pump schedule on the drawings. Provide pumps of the same type by the same manufacturer.

B. Motors: Open, drip-proof type. Provide motors, which are non-overloading at any point on the pump curve, with built-in overload protection on single-phase motors. The scheduled motor horsepowers are evaluated minimums and larger motors shall be submitted and furnished if necessary to meet the non-overloading requirement.

C. Circulating Pumps: Self-sensing pumps shall be as follows, or approved equal:

Taco SKV Series Self-Sensing with ‘ProBalance’ Technology
Bell & Gossett Series 80 Sensorless with ‘ITSC’ Option

1. Pump Description
   a. Pumps shall be of the in-line vertical close coupled type.
   b. Pumps shall have a cast iron casing and cast bronze impeller suitable for 175 psi working pressure at 225°F, and shall be split-coupled.
   c. Pumps shall be fitted with stainless steel shaft, internally flushed mechanical shaft seals, and ball bearings of ample size to withstand all thrust and radial loads. Bearings shall be heavy duty re-greaseable ball bearings. Impellers shall be fully enclosed and hydraulically balanced. Low points of casings shall be provided with valved drains and inlet and outlet connections shall be provided with properly located gauge tappings.
   d. Motors shall 1750 rpm, TEFC, shall meet NEMA specifications, and shall be premium efficiency type compatible with the associated variable speed drives. Pumps shall be non-overloading at any point on the performance curve.
2. Integral Pump Controller
   a. The control system and integrated logic shall be factory developed, tested and installed on the pump at the factory and contained as part of a VFD system within a common enclosure.
   b. The control package shall include safeties to protect from motor overload, pump surging, hydraulic cycling and operation in unstable conditions.
   c. The system shall maintain the required pump flow and pressure based upon the actual system curve of the hydronic system imbedded into the software.
3. Variable Frequency Drives
   a. Furnish variable frequency drives in the numbers and voltages shown on the plans and with the amperage ratings listed below. VFD's shall be UL or ETL listed and meet NEMA and IEEE 587 and shall communicate as BACnet buss. VFD’s shall be compatible with the associated motors.
   b. Variable frequency drives must be provided, installed, and tested by the pump manufacturer.

4. Hardware
   a. Variable Frequency Drive Systems shall be microprocessor based, fully transistorized with a conservatively rated 3-phase full wave diode bridge input and a PWM sine-coded output waveform. The VFD's shall be tested and rated for a minimum of 20 years Mean Time Between Failure (MTBF).
   b. The inverter manufacturer shall have a minimum of 5 years of experience in manufacturing inverters and shall have a minimum of 4 years of experience with IGBT transistors used with the inverter to produce the output PWM waveform, allowing quiet motor operation. Inverters with carrier frequencies below 12kHz will not be acceptable.
   c. The 5 through 40 HP, 208 VAC adjustable speed drive shall be a pulse width modulated (PWM) design that has a carrier frequency of 12 KHz or higher so no acoustic noise will be produced onto the motor. The adjustable speed drive shall maintain a 120% current overload capability for 60 seconds with automatic stall prevention and voltage boost to prevent nuisance tripping during load or line side transient conditions. The adjustable speed drive shall maintain a power factor of not less than 0.95 throughout its speed range.
   d. The inverters shall be rated for continuous duty at a 10 Hz carrier frequency on the motor full load currents listed from NEC Table 430-150. If derating of the inverter is necessary to run at 12 kHz, then the units must be de-rated and their new de-rated currents must equal or exceed the motor full load currents.

      The insulated Gate Bipolar Transistors (IGBTs) shall have a minimum rating of 1000VDC on 380/460/480VAC and 500VDC on 208/230VAC units.
   e. Enclosure: The VFD shall have a metal NEMA 1 enclosure for reduction of radio frequency and electromagnetic interference. Plastic enclosures are not acceptable. The enclosure shall be wall mount. The enclosure door shall be hinged for easy access and all internal components shall be easily accessible.
   f. The adjustable speed drive shall have, as a minimum, the following design features as standard:
      1) 12 KHz sine-coded, pulse width modulated output.
      2) Overload capability of 120% for 60 seconds. 110% continuous.
      3) Process follower 4-20mADC, 0-5VDC, or 0-10VDC input.
      4) An LCD digital readout displaying output frequency, status, percent current, percent voltage, and response signal.
      5) Current limiting circuit.
      6) Acceleration and deceleration adjustable from 1 - 1200 seconds.
      7) In addition to the inverter's self-diagnostic features, the drive shall have a form C contact (1NO, 1NC) for remote indication of fault.
      8) Customer interlock for remote starting and stopping.
      9) On loss of speed reference signal, the drive shall operate at a preset minimum speed so that the inverter will not drive the fan at a speed capable of causing system problems.
      10) The drive shall provide a 24VDC open collector output signal which will indicate when the drive is running, and when the drive is at a certain preset speed.
      11) The drive shall be capable of restarting into a rotating motor by sensing the frequency of the rotating motor and starting into the motor at that frequency.

12) The drive shall have a digital keypad for performing all parameter adjustments and programming which shall include the following features:
    a) Quick setup key to allow for simple setup and expeditious startup.
    b) Manual/Off/Auto keys for selection of control mode.
    c) Fault clear/reset key.
    d) Run and stop keys for starting and stopping in manual mode.
    e) Up and Down arrow keys for adjustment of motor speed and adjustment of programming parameters.
    f) Program key for entering program mode for adjustment of parameters.
    g) Read/write key for changing parameters in program mode.
13) The inverter shall have a 3% input line reactor in addition to an integral 5% DC link reactor.
14) The drive shall be equipped with critical frequency avoidance where it shall be capable of avoiding up to three resonant points in the mechanical system.
15) A user programmable personal lockout code shall prevent unauthorized programming of the inverter.
16) Integral disconnect switch.

g. The adjustable speed drive shall have, as a minimum, the following protective features:
    1) Ground fault protection.
    2) Thermal motor overload relay (where inverter bypass option is used).
    3) Current limit adjustable from 10% - 100%.
    4) Current limited stall prevention during acceleration, deceleration, and run conditions.
    5) Automatic restart after momentary power loss or momentary overvoltage. The drive shall not restart into faults other than overvoltage, undervoltage, or overcurrent due to acceleration rate set too fast, because other faults, such as an overcurrent due to a blown transistor or a short circuit on the output, could cause damage to the inverter.
    6) Fault indicators shall indicate the following fault conditions. Faults shall be displayed by flashing on the LCD display on the front panel of the inverter. When a fault occurs, the drive shall have built-in diagnostic functions that assist in determining the cause and source of the fault. The drive shall indicate the current, voltage, and frequency at the time of the fault.
        a) Overcurrent during acceleration (OC1) and deceleration (OC2)
        b) Overcurrent while running (OC3)
        c) Overcurrent on output (OCL)
        d) Overcurrent detected at startup (OCA)
        e) Overload (OL)
        f) Overvoltage during deceleration (OP2)
        g) Overvoltage due to power surge (OP)
        h) Over temperature (OH)
        i) Ground Fault (EF)
        j) Emergency Stop (E)
        k) Frequency Setting Fault (EFF)
        l) EEPROM Abnormality (EEP)
        m) EEPROM Abnormality (EEP2)
        n) EEPROM Abnormality (EEP3)
        o) Computer Link Abnormality (Err.t)
        p) Power Supply Undervoltage (POFF)
        q) DC Main Circuit Undervoltage (nOFF)
    7) Current limiting DC bus fuse.
    8) Phase-to-phase short circuit protection.

h. The adjustable speed drive shall have the following adjustments available under the Setup key:
   1) Acceleration - 1.0 to 1200 seconds.
   2) Deceleration - 1.0 to 1200 seconds.
   3) Maximum frequency range.
   4) Maximum frequency (0 to 100% speed).
   5) Bias and gain adjustment for 4-20mA, 0-5VDC, 0-10VDC follower. (Can be direct or indirect acting).
   6) Thermal overload adjustment (10-100%).

i. The adjustable speed drive shall be designed to operate within the following environmental and service conditions.
   1) Ambient service temperature: -10 C to 40 C.
   2) Ambient storage temperature: -20 C to 60 C.
   3) Humidity: Non-condensing to 90% RH.
   4) Altitude to 3300 feet and de-rated for specific project site conditions.
   5) Service factor: 1.1.
   6) Input voltage: Three phase 460/480VAC +/- 10% for 460VAC series.
   7) Input frequency: 50/60 hertz +/- 3%.

j. Accessories to be furnished and mounted by the drive manufacturer:
   1) Door interlocked circuit breaker (25,000 AIC) which will disconnect all input power from the drive and all internally mounted options. The disconnect handle shall be through-the-door type, and be pad-lockable in the off position. A disconnect switch is not acceptable as this will protect neither the inverter nor the motor.
   2) BACnet or LonWorks interface as selected by the temperature control contractor and the Owner. The temperature control contractor shall provide programming for 15 points per drive as directed by the Architect/Engineer.

k. The adjustable speed drive shall be designed and built to the following standards:
   1) UL or ETL listed.
   2) NEMA listed.
   3) IEEE 587.

5. Startup and Warranty
   a. The VFD startup shall be by a trained or certified technician familiar with the VFD and the installation described herein. A startup report, listing all constants, their proper adjustment, and the name of the technician shall be submitted with the operation and maintenance data required for this project. Include demonstration and training for the Owner’s maintenance personnel.
   b. The manufacturer shall not rely on the field services of the installing contractor to perform the startup unless that contractor has factory certified technicians on staff. Startup shall be included in the bid.
   c. Warranty shall be for two years from date of acceptance by the Owner. Warranty service technicians shall be factory trained and certified, and available for telephone response within 1 hour, and response to the project site within 24 hours.

PART 3 - EXECUTION

3.1 CARE AND CLEANING

A. Repair or replace broken, damaged, or otherwise defective parts, materials, and work. Leave entire work in condition satisfactory to Architect/Engineer. At completion, carefully clean and adjust equipment and trim installed as part of this work. Leave systems and equipment in satisfactory operating condition.

3.2 OPERATION TEST

A. Test each piece of equipment to show that it will operate in accordance with the indicated requirements.

3.3 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like, and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 21 00 - HYDRONIC PIPING AND ACCESSORIES

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

1.2 WORK INCLUDED

A. Types of hydronic piping and pumping systems specified in this section include the following:

Hydronic Piping, Valves, and Fittings
Heating Water Piping
Condensate Drain Piping

Hydronic Accessories
Valves
Air and Dirt Separators
Expansion Tanks
Flexible Connections
Strainers
Reduced Pressure Backflow Preventers
Chemical Feeders
Propylene Glycol Feed Systems

1.3 QUALITY ASSURANCE

A. Manufacturer's Qualifications: Firms regularly engaged in manufacture of hydronic piping products of types, materials, and sizes required, whose products have been in satisfactory use in similar service for not less than 5 years.

B. Acceptable Manufacturers: Subject to compliance with requirements, manufacturers offering pumping equipment which may be incorporated in the work include the following:

Taco
Bell and Gossett

C. UL Compliance: Provide electric components for pumps which are UL listed.

D. Codes and Standards

1. ASME Compliance: Fabricate and install hydronic piping in accordance with ASME B31.9 (Code for Building Services Piping).
2. UMC Compliance: Fabricate and install hydronic piping in accordance with the Uniform Mechanical Code.

1.4 SUBMITTALS

A. As-Built Drawings: At project closeout, submit as-built drawings of installed hydronic pumps, piping, and hydronic specialties in accordance with all associated requirements.

B. Operation and Maintenance Data
   1. Submit operation and maintenance data and parts lists for hydronic piping materials and products. Include this data, product data, shop drawings, and as-built drawings in operating and maintenance manual in accordance with all associated requirements.
   2. Submit operation and maintenance data and parts lists for each type of pump, control, and accessory, including trouble-shooting maintenance guides.

C. Product Data
   1. Submit manufacturers pump specifications, installation and start-up instructions, and current accurate pump characteristic performance curves with selection points clearly indicated. Pump efficiencies, as well as construction, will be taken into consideration.
   2. Submit manufacturer's technical product data and installation instructions for each type of hydronic specialty.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Provide piping materials and factory-fabricated piping products of sizes, types, pressure ratings, temperature ratings, and capacities as indicated. Provide materials and products complying with ASME B31.9 (Code for Building Services Piping) where applicable, base pressure rating on hydronic piping systems maximum design pressures or as specified. Provide sizes and types matching piping and equipment connections; provide fittings of materials which match pipe materials used in hydronic piping systems.

2.2 GENERAL PIPE AND PIPE FITTING REQUIREMENTS

A. General
   1. Provide pipe and tubing, joint type, grade, size, and weight indicated for each service, and complying with all governing regulations and industry standards.
   2. Remove scale, oxidation, slag, oil, grease, rust, dirt, and debris from inside and outside of pipe and fittings prior to assembly. Ream ends of pipe and tubes to remove burrs. Bevel plain ends of steel pipe.
   3. Cut all pipe threads using sharp dies. Tapered threads shall comply with ASME B1.20.1.

B. Steel Pipe and Pipe Fittings
   1. When Schedule 40 black steel pipe is specified in sizes 12” and larger the wall thickness shall be .375” to match the associated fitting thickness.
   2. Black Steel Pipe: ASTM A53, A106, or A120; except comply with ASTM A53 or A106 where close coiling or bending is required.
   3. Galvanized Steel Pipe: ASTM A53 or A120; except comply with ASTM A53 where close coiling or bending is required.
   4. Malleable Iron Threaded Fittings: ANSI B16.3; plain or galvanized to suit piping. For use above grade only, except where indicated otherwise.
   5. Malleable Iron Threaded Unions: ANSI B16.39; selected by the Contractor for proper piping fabrication and service requirements, including style, end connections, and metal-to-metal seats (iron, bronze, or brass), plain or galvanized as indicated.
   6. Forged Steel Socket Welding and Threaded Fittings: ANSI B16.11, except MSS SP-79 for threaded reducer inserts; rated to match schedule of connected pipe.
   7. Wrought Steel Butt-Welding Fittings: ANSI B16.9, except ANSI B16.28 for short radius elbows and returns; rated to match connected pipe.

8. Pipe Nipples: Fabricated from same pipe as used for connected pipe, except do not use less than Schedule 80 pipe where the length remaining unthreaded is less than 1-1/2 inches and where the pipe size is less than 1-1/2 inches. Do not thread nipples full length (no close nipples are allowed).

C. Copper Tube and Fittings
   1. Copper Tube: ASTM B88; Type L, hard drawn temper, except as otherwise indicated.
   2. Wrought Copper Solder Joint Fittings: ANSI B16.22.

D. Elbows
   1. All elbows in hydronic piping systems shall be long radius.
   2. Short radius elbows shall be utilized only where necessitated by space constraints. Such instances shall be submitted to the Engineer for review and approval.

E. Miscellaneous Piping Materials/Products
   1. General: Where applicable all pipe joining methods shall comply with the requirements of the ASME Boiler and Pressure Vessel Code.
   2. Welded Joints: Except as otherwise indicated, provide welding materials as determined by the Contractor to comply with all installation requirements and to comply with Section II, Part C, ASME Boiler and Pressure Vessel Code for welding materials.
   3. Soldered Joints: Construct joints in accordance with ASTM B828 or the Copper Development Association 'Copper Tube Handbook' using lead free solder complying with ASTM B32. Apply ASTM B813 water-flushable flux, to tube ends, unless otherwise indicated.
   4. Brazed Joints: Construct joints in accordance with American Welding Society 'Brazing Handbook' using a copper-phosphorus brazing filler metal complying with American Welding Society Section A5.8 and with the ASME Boiler and Pressure Vessel Code.
   5. Comply with SFA-5.8, Section II, ASME Boiler and Pressure Vessel Code for brazing filler metal materials.
   6. Gaskets for Flanged Joints: ANSI B16.21; full faced for cast iron flanges; raised face for steel flanges, unless otherwise indicated.

2.3 PIPE AND PIPE FITTING SYSTEMS

A. Heat Recovery Water Piping Indoors
   1. ASTM A53 or ASTM A120 Schedule 40 black steel with standard weight, long radius, butt-welding fittings and 150 lb forged steel, weld-neck type flanges. Connections to threaded equipment, valves, etc. shall be made with 150 lb cast iron, threaded fittings. Piping 2 inches and smaller shall have 150 lb screwed, cast iron fittings. Slip-on flanges will be permitted where space is limited with prior written approval by the Architect/Engineer. All slip-on flanges shall be back-welded.
   2. Chilled water piping 2" and under may be copper tube; ASTM B 88 Type L, hard drawn temper with wrought copper fittings and brazed joints.

B. Heating Water Piping Indoors
   1. ASTM A53 or ASTM A120 Schedule 40 black steel with standard weight, long radius, butt-welding fittings and 150 lb forged steel, weld-neck type flanges. Connections to threaded equipment, valves, etc. shall be made with 150 lb cast iron, threaded fittings. Piping 2 inches and smaller shall have 150 lb screwed, cast iron fittings. Slip-on flanges will be permitted where space is limited with prior written approval by the Architect/Engineer. All slip-on flanges shall be back-welded.
   2. Heating water piping 2" and under may be copper tube; ASTM B88 Type L, hard-drawn temper, with wrought copper fittings and brazed joints.

C. Cooling Coil Condensate Drain Piping: Type L, hard copper tubing with wrought copper solder joint fittings and 95 percent tin, 5 percent antimony solder. Condensate drain piping 1" and smaller shall use 45 degree wyes and long radius fittings at all changes in direction. Condensate drain piping 1-1/4" and larger shall use DWV fittings.

D. Air Vent Discharge Piping: Type L hard copper tubing with wrought copper solder joint fittings and 95 percent tin, 5 percent antimony solder.

2.4 HYDRONIC PIPING INSTALLED OUTDOORS

A. For projects that include hydronic piping that is indicated to be installed outdoors see Specification Section 232170 (Hydronic Piping Installed Outdoors).

2.5 HYDRONIC ACCESSORIES

A. Hydronic Valves
   1. Provide valves complying with Section 230510 (Valves for HVAC Systems).

B. Air and Dirt Separators
   1. Provide in-line air and dirt separators of size and capacity as indicated on the drawings. Tank shall be constructed of carbon steel and pressure rated for 125 psi at 270°F in compliance with ASME Boiler and Pressure Vessel Code Section VIII. Air and dirt separators shall include an integral magnetic dirt filter and a removeable head. Separator shall have stainless steel pall rings
   2. Available Manufacturers: Subject to compliance with requirements, manufacturers offering air and dirt separators which may be incorporated in the work include the following, or approved equal:

      Taco Model 4900-ADM
      Thrush
      Spirotherm

C. Expansion Tanks
   1. Replaceable bladder type. Shell and heads shall be of carbon steel welded construction in accordance with ASME Section VIII for 125 psi working pressure. Provide full volume flexible butyl rubber bladder, bottom system connection, air charging fitting, drain connection, lifting eye, and base ring for vertical mounting. Factory pre-charge as indicated on drawings.
   2. Install a ball valve with lockshield at all expansion tanks. Ball valves with lockshield shall be Crane Model D171, or approved equal.
   3. Available Manufacturers: Subject to compliance with requirements, manufacturers offering expansion tanks which may be incorporated in the work include the following, or approved equal:

      Taco
      Elbi

D. Flexible Connections (Pumps)
   1. Provide flexible connections where indicated on the drawings and/or as required to accommodate movement or vibration of the piping system.
   2. Flexible connections shall be all stainless steel with carbon steel flanges and a 1/16" lateral offset capability. Flexible connections shall be rated for a minimum working pressure of 200 psi at 70°F. Flexible connections shall be Twin City Hose Model TCHS, or approved equal.

E. Flexible Connections (Air Handling Units)

1. Provide flexible connections where indicated on the drawings and/or as required to accommodate movement or vibration of the piping system.
2. Flexible connections shall be all stainless steel with carbon steel flanges and a 1/16” lateral offset capability. Flexible connections shall be rated for a minimum working pressure of 200 psi at 70°F. Flexible connections shall be Twin City Hose Model TCHS, or approved equal.

F. Flexible Connections (Fan Coil Units, Motorized Equipment)

1. Provide 18 inch long flexible connections where indicated on the drawings and/or as required to accommodate movement or vibration of the piping system.
2. Flexible connections shall be all stainless steel with carbon steel ends. Flexible connections shall be rated for no less than 370 psi working pressure at 70°F. Flexible connections shall be Twin City Hose Model HPH, or approved equal.

G. Wye Strainers

1. Provide wye strainers of size and capacity as indicated on the drawings. Strainers shall be constructed of epoxy painted cast iron or ductile iron, shall be ANSI Class 125, rated for 200 psi at 150°F, with pressure tappings to allow for assessment of strainer pressure drop. Wye strainers shall be constructed of stainless steel with .015” openings (40 mesh).
2. Available Manufacturers: Subject to compliance with requirements, manufacturers offering wye strainers which may be incorporated in the work include the following, or approved equal:

   Titan Flow Control Model YS-58-CI
   Zurn Wilkins Model FSC

H. Reduced Pressure Backflow Preventers

1. Provide reduced pressure principle backflow preventers consisting of complete assembly, including ball type shutoff valves on inlet and outlet, strainer on the inlet, and oversized air gap fitting. Backflow preventers shall include test valves and a pressure differential relief valve located between two positive seating check valves.
2. Air gap fitting sizes shall be as follows:

1” and 1-1/2” backflow preventer:	3” air gap fitting and drain piping
2” and 2-1/2” backflow preventer:	4” air gap fitting and drain piping
3” and 4” backflow preventer:	6” air gap fitting and drain piping
5” and 6” backflow preventer:	8” air gap fitting and drain piping

3. Available Manufacturers: Subject to compliance with requirements, manufacturers offering backflow preventers which may be incorporated in the work include the following, or approved equal by Apollo or Watts:

   Zurn Wilkins Model 375XL or BF-475 (depending on water line size and flow)

I. ~~Chemical Feeders - See Specification Section 232500 (Chemical Treatment).~~ NOT USED.

J. Propylene Glycol Feed Systems

1. Propylene glycol feed system shall be as called out on the drawings, or approved equal.
2. Provide a propylene glycol concentration tester for each glycol feed system for use by the Owner. Propylene glycol concentration tester unit shall be PCE Americas PCE-DR Series Digital Refractometer, or approved equal.

PART 3 - EXECUTION

3.1 INSPECTION

A. Examine areas and conditions under which hydronic piping systems and specialties are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected.

3.2 INSTALLATION OF PIPING

A. The drawings, details, and diagrams indicate the general location and arrangement of the piping systems. The indicated piping locations and arrangements were utilized to determine appropriate pipe sizes and to calculate piping friction loss, expansion, system volume, pump sizes, and for other design considerations. Install piping as indicated unless deviations to the layout are identified and approved as part of the Contractor's shop drawings or submittals.

B. Install pipes and pipe fittings in accordance with recognized industry practices which will achieve permanently leak-proof piping systems, capable of performing each indicated service without piping failure.

C. Install each pipe run with minimum joints and couplings but with adequate and accessible unions for disassembly and maintenance/replacement of valves and equipment. Reduce sizes where indicated by use of reducing fittings. Align piping accurately at connections, within 1/16 inch misalignment tolerance.

D. Locate piping runs, except as otherwise indicated, vertically and horizontally (pitched to drain), avoiding diagonal runs wherever possible. Orient horizontal runs parallel with walls and column lines. Locate runs as shown or described in drawings, diagrams, details, and notations. If not otherwise indicated, run piping in the shortest route which does not obstruct usable space or block access for servicing the building and the equipment.

E. Hold piping close to walls, overhead construction, columns, and other structural and permanent building elements. Limit clearance to 1/2" where furring is shown for enclosure/concealment of piping. Locate insulated piping with 1" clearance outside of the insulation.

F. Wherever possible in finished and occupied spaces, conceal piping from view by locating in column enclosures, in hollow wall construction, or above suspended ceilings; do not encase horizontal runs in solid partitions, except as indicated.

G. Electrical Equipment Spaces: Do not run piping through transformer vaults or other electrical or electronic equipment spaces and enclosures unless unavoidable. Install a drip pan under piping that must be run through electrical spaces and in all other locations indicated on the drawings.

H. Should structural difficulties or work of other contractors prevent the routing of pipes or the setting of equipment at the points shown on the drawings, the necessary deviations therefrom, as determined by the Contractor, with the Architect/Engineer's review and acceptance, will be allowed but must be made without additional cost to the Owner.

I. Inspect each piece of pipe and each fitting to see that there is no defective workmanship on pipe or obstructions in pipes and fittings.

J. Install exposed polished or enameled connections from fixtures or equipment with special care, showing no tool marks or threads at fittings.

K. Cap or plug openings in pipe and fittings immediately to exclude all dirt until fixtures are installed or final connections made.

L. Use reducing fittings where any change in pipe size occurs. Bushings shall not be used.

M. Condensate Drain Piping: Run piping with downward pitch as indicated, without pockets.

N. Grade water circulating piping used for space heating and/or cooling up to high points at the rate of 1/4 inch in 10 feet in the direction of flow with returns grading down at same rate. Air vent valves specified hereinafter shall be installed at high points. Changes in pipe sizes shall be made with eccentric reducers flat on top.

O. Couplings shall not be used except where required pipe runs between fittings are longer than a standard length of the type of pipe being used and except where their use is specifically reviewed by the Architect/Engineer.

P. Conceal piping in finished portions of building, above the floor line, except where otherwise shown or noted. Cutting of walls and floors shall be held to the minimum possible to secure the proper installation.

Q. Install piping subject to expansion or contraction in a manner permitting strains to be evenly distributed and alleviated by expansion loops installed as required.

R. Sleeves for branches through walls from adjacent mains shall be of sufficient size to allow for free side motion of covered pipe in sleeve.

3.3 INSTALLATION OF VALVES

A. All valves shall be installed in locations that are reasonably accessible without the use of a ladder unless otherwise indicated on the drawings (such as in the case of valves equipped with chain operators).

B. Drain Valves: Install at each mechanical equipment item located to completely drain equipment for service or repair. Install at base of each riser, at base of each rise or drop, and elsewhere as indicated or required to completely drain each piping system

C. Check Valves: Install on the discharge side of each pump and elsewhere as indicated.

3.4 INSTALLATION OF HYDRONIC ACCESSORIES

A. Balance Valves: Install balance valves on each hydronic terminal and elsewhere as indicated. After hydronic system balancing has been completed, mark each balance valve with stripe of yellow lacquer across body and stop plate to permanently mark final balanced position.

B. Manual Vent Valves: Install manual vent valves on each hydronic terminal at the highest point and on each hydronic piping drop in the direction of flow for mains, branches, runouts, and elsewhere as indicated on the drawings.

C. Automatic Vent Valves: Install automatic vent valves at the top of each hydronic riser and elsewhere as indicated on the drawings. Install a shutoff valve between each riser and vent valve, pipe the outlet to a suitable plumbing drain or as indicated on the drawings.

D. In-Line Air Separators

1. Route piping to expansion tank with 1/4 inch per foot upward slope towards tank.
2. Install drain valve on all air separators.

E. Bladder Type Expansion Tanks: Install diaphragm type expansion tanks on floor as indicated, in accordance with manufacturer's instructions. Vent and purge air from hydronic system and charge tank with proper air charge as indicated on the drawings. Coordinate the charge pressure with the fill pressure to ensure flow to highest coil in system.

F. Chemical Feeders: Install in upright position with top of funnel not more than 48 inches above finished floor. Install balance valve in pump discharge line to allow for adjustment of the desired flow out of the chemical feeder. Pipe drain to nearest plumbing drain or as indicated.

3.5 INSTALLATION OF HANGERS AND SUPPORTS FOR PIPING SYSTEMS

A. See Specification Section 230530 (Hangers and Supports for HVAC Piping, Ductwork, and Equipment). Where special hanging or support of ductwork or piping is detailed or shown on the drawings, the drawings shall be followed.

3.6 EQUIPMENT CONNECTIONS

A. Connect hydronic piping system to mechanical equipment as indicated, and comply with equipment manufacturer's instructions where not otherwise indicated. Install shutoff valve and union on supply and return; drain valve on drain connection.

3.7 TESTING OF PIPING

A. Test piping in accordance with the following schedule. There shall be no loss in pressure and no visible leaks after a minimum duration of four hours at the test pressures indicated.

System Tested	Test Pressure	Test With
Chilled Water Piping Heating Water Piping (250°F & Under) Heat Pump Loop Water Piping	150 psi at rough-in and 100 psi after equipment connection	Water

3.8 CLEANING OF HYDRONIC PIPING SYSTEMS AND EQUIPMENT

A. System Preparation
   1. System shall be operational prior to cleaning.
   2. Make temporary piping connections and provide a temporary bypass filter to properly accomplish cleaning the entire system. Provide temporary pumps when indicated on the drawings and/or when necessary to protect the new pumps from contamination/debris in an existing piping system.
   3. Place all manual, pressure regulating and control valves serving the system in open position during cleaning so that circulation through the system is obtained during cleaning.
   4. Verify that electric power is available and of the correct characteristics for any cleaning equipment.

B. Cleaning Sequence
   1. Any and all cleaning and flushing procedures outlined in this section ~~and in Section 232500 (Chemical Treatment)~~ shall occur before any piping is connected to the heat pump equipment or any other coils (*No Exceptions*). No flushing will be permitted after any equipment and/or coils are connected to the system.
   2. Projects with distribution to/from other buildings or to a ground source bore field: Provide a temporary basket strainer with .125” perforations to protect the piping inside the building from the ground loop piping outside the building. The ground loop piping shall be flushed and cleaned prior to connecting to the piping inside the building.
   3. If any equipment and/or coils are connected to the system during cleaning and flushing procedures, the Owner has the right to have each affected water coil replaced with a new factory coil at no cost to the Owner.
   4. Initial Flush (all hydronic systems)
      a. 1st filling: Completely fill the system with fresh water and circulate at 6 feet per second for 4 hour minimum.
      b. Initial flushing shall be sufficient to remove all contaminants such as cuttings, filings, loose rust and scale, welding and soldering, residue and debris.
      c. 2nd filling: Drain the entire system and refill with fresh water.

5. Cleaning Flush
    1. Use concentrated chemical cleaner in piping system. Cleaner shall be a solution consisting of 2 lbs tri-sodium phosphate for each 1000 lbs of water contained in the system.
    2. Circulate the solution at 6 feet per second for the recommended time period corresponding to the cleaning fluid temperature.
        a. Partially close and reopen all manual valves twice during the flushing duration.
            1) Test solution for proper concentration and document results.
            2) Completely drain the entire system.
        b. 3rd filling: Refill the system with fresh water. Then, with the circulation pump running, open drain(s) as far downstream from the fill point as is possible. Ensure makeup is sufficient to keep up with the drain to maintain a full system.
        c. Partially close and reopen all manual valves twice during the flushing duration.
        d. Blowdown all strainers, dead legs and low points in the system.
        e. Continue to flush the system in this manner until the drain water is of the same clarity as the makeup water and testing reveals no further traces of cleaning solution (flush for minimum of 1 hour). Document the results.
        f. Following the fresh water flush, drain the entire system.
        g. Clean all strainers, and then fill and treat the entire system.

3.9 CARE AND CLEANING

A. Repair or replace broken, damaged, or otherwise defective parts, materials, and work. Leave entire work in condition satisfactory to Architect/Engineer. At completion, carefully clean and adjust equipment and trim installed as part of this work. Leave systems and equipment in satisfactory operating condition.

3.10 OPERATION TEST

A. Test each piece of equipment to show that it will operate in accordance with the indicated requirements.

3.11 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like, and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 22 00 - HYDRONIC PUMPS

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

1.2 WORK INCLUDED

A. This section includes various pump types and pump accessories.

1.3 QUALITY ASSURANCE

A. Manufacturer's Qualifications: Firms regularly engaged in manufacture of hydronic piping products of types, materials, and sizes required, whose products have been in satisfactory use in similar service for not less than 5 years.

B. Acceptable Manufacturers: Subject to compliance with requirements, manufacturers offering pumping equipment which may be incorporated in the work include the following, or approved equal:

Taco
Bell and Gossett
Grundfos

C. UL Compliance: Provide electric components for pumps which have been listed by Underwriters Laboratories.

D. Codes and Standards

1. ASME Compliance: Fabricate and install hydronic piping in accordance with ASME B31.9 (Code for Building Services Piping).
2. UMC Compliance: Fabricate and install hydronic piping in accordance with the Uniform Mechanical Code.

1.4 SUBMITTALS

A. As-Built Drawings: At project closeout, submit as-built drawings of installed hydronic pumps, piping, and hydronic specialties in accordance with all associated requirements.

B. Operation and Maintenance Data

1. Submit operation and maintenance data and parts lists for each type of pump, control, and accessory, including trouble-shooting maintenance guide. Include this data and product data in the operation and maintenance manual, in accordance with all associated requirements.

C. Product Data

1. Submit manufacturers pump specifications, installation and start-up instructions, and current accurate pump characteristic performance curves with selection points clearly indicated. Pump efficiencies, as well as construction, will be taken into consideration.
2. Submit manufacturer's technical product data and installation instructions for each type of hydronic specialty.

PART 2 - PRODUCTS

2.1 HYDRONIC PUMPS

A. General: Provide factory tested pumps, thoroughly cleaned, and painted with one coat of machinery enamel prior to shipment. Type, size, and capacity of each pump as listed in pump schedule. Provide pumps of same type by same manufacturer.

B. Motors (Open Drip Proof): Provide motors, which are non-overloading at any point on the pump curve, with built in overload protection on single phase motors. The scheduled motor horsepowers are evaluated minimums and larger motors shall be submitted and furnished if necessary to meet the non-overloading requirement. Pump motors shall be premium efficiency type as defined in NEMA MG1.

C. Close-Coupled In-Line Pumps (with EC Motor)

1. Pump capacities and characteristics shall be as identified on the plans and in the pump schedule(s). Pumps shall be Taco Viridian Series, Taco 1900E Series, Grundfos Model Magna3, or approved equal. Pumps shall be variable speed, EC Motor, in-line type, designed for installation with the pump mounted horizontally or vertically.
2. Pump casing shall be cast or ductile iron (stainless steel for potable water applications) with threaded gauge tappings at inlet and outlet.
3. Pump impeller shall be stainless steel or composite**,** statically and dynamically balanced, with a stainless steel shaft.
4. Pump shall include a digital display, 0-10 volt dc control input for the EC motor, and a status indicating light.

2.2 PUMP ACCESSORIES AND INSTALLATION

A. All pumps shall be fitted with suction and discharge isolation valves, flexible connections, and a check valve to prevent reverse flow.

B. Check valves 2-1/2” and larger shall be iron body, silent, vertical spring type, Nibco Model F-910, Titan Model CV-50-DI, or approved equal. Check valves 2” and smaller shall be bronze or brass body, silent, vertical spring type, Nibco Model T-480, Titan Model CV-20-BR, or approved equal.

C. All pumps shall be fitted with one 4-1/2” dial pressure gauge piped to the inlet and outlet pump flanges. The gauge shall be isolated from each flange via 1/4” ball valves. The gauge is intended to be used to read the differential across the pump.

D. The Contractor shall install pumps in accordance with the pump manufacturer’s written instructions. The Contractor shall level and align each pump.

E. Pumps shall not be run dry to check rotation.

F. Pipe connections to pumps shall be made in a manner so as not to exert any stress on the pump housing(s). If necessary to meet this requirement, provide additional pipe supports.

PART 3 - EXECUTION

3.1 INSTALLATION OF PUMPS

A. Install pumps where indicated, in accordance with manufacturer's published instructions, complying with recognized industry practices to ensure that pumps comply with requirements and serve intended purposes.

B. Provide access space around pumps for service as indicated, but in no case less than that recommended by manufacturer.

C. Install base-mounted pumps on minimum of 4 inch high concrete pad, with anchor bolts poured in place. Set and level pump; grout under pump base with non-shrink grout. Provide drain line to nearest floor drain or floor sink.

D. Install in-line pumps with support from overhead structure on each side of pump, or as indicated on the drawings.

E. Piping shall be supported from the building structure so as to prevent any strain on the pump casings. A final check for perfect alignment of the piping connections shall be made after pump has been secured to its base. Provide valves, accessories, gauges, supports, and flexible connections, as indicated on the drawings and in these specifications.

F. Install electrical devices furnished by the pump manufacturer but not specified to be factory mounted. Coordinate the pump manufacturer's wiring diagram submittal with the electrical subcontractor.

G. Verify that the electrical wiring installation is in accordance with the pump manufacturer's submittal and with the installation requirements listed in Division 26. Do not proceed with equipment startup until the wiring installation is complete and correct.

H. Check alignment, and where necessary, realign shafts of motors and pumps within the recommended tolerances provided by the manufacturer.

I. Lubricate pumps before startup. Startup procedures shall be conducted in accordance with the manufacturer's written instructions.

J. Pumps shall not be connected to piping before piping is thoroughly flushed and cleaned of all dirt and grit. After piping connections have been made, systems shall be filled before starting pumps. Pumps shall not be run dry under any circumstances.

K. For base-mounted, end-suction pumps, comply with the requirements in ANSI HI standards for alignment of pump and motor shaft. Add shims to the motor feet and bolt the motor to the base frame. Do not use grout between motor feet and base frame.

L. For base-mounted, end-suction pumps, after alignment is correct, tighten foundation bolts evenly, but not too firmly. Completely fill the baseplate with non-shrink, non-metallic grout while metal blocks and shims or wedges are in place. After the grout has cured, fully tighten the foundation bolts.

M. Training: Provide a minimum of 4 hours of training and orientation of the Owner’s operating staff in proper care and operation of equipment, systems, and controls.

3.2 CARE AND CLEANING

A. Repair or replace broken, damaged, or otherwise defective parts, materials, and work. Leave entire work in condition satisfactory to Architect/Engineer. At completion, carefully clean and adjust equipment and trim installed as part of this work. Leave systems and equipment in satisfactory operating condition.

3.3 OPERATION TEST

A. Test each piece of equipment to show that it will operate in accordance with the indicated requirements.

3.4 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like, and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 24 00 - REFRIGERANT PIPING AND ACCESSORIES

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

1.2 WORK INCLUDED

A. Refrigerant piping and accessories as indicated on the drawings and as specified herein.

1.3 SUBMITTALS

A. Product Data: Submit manufacturer's technical product data and installation instructions for refrigerant piping systems.

1.4 QUALITY ASSURANCE

A. Flammable refrigerant piping systems shall be installed and tested in strict accordance with ASHRAE Standard 15, including Sections 9.12 (Refrigerant Systems Installation) and 9.13 (Refrigerant Systems Testing).

B. For all flammable refrigerant systems containing 55 lbs or more of refrigerant, the installing contractor shall submit a certificate to the Architect/Engineer and the Owner verifying that the required strength testing and leakage testing has been successfully performed as described in ASHRAE Standard 15 Section 9.13 (Refrigerant Systems Testing).

PART 2 - PRODUCTS

2.1 REFRIGERANT PIPING REQUIREMENTS

A. Refrigerant Piping: Type ACR-L hard drawn copper refrigerant tubing with wrought copper solder joint fittings. All joints shall be brazed. Soft drawn copper line sets are not acceptable.

B. Piping Components: The following refrigerant piping components shall be provided (*except on mini-split heat pumps and variable refrigerant systems*).

1. Condensing Unit Service Valves (if not provided integral to the condensing unit by the condensing unit manufacturer (Emerson BV Series, Henry 907 Series, or approved equal).
2. Sight Glass (Emerson HMI Series, Henry MI Series, or approved equal).
3. Filter-Drier (Emerson EK Series, Henry SDM Series, or approved equal).

2.2 REFRIGERANT PIPING INSULATION

A. See Specification Section 230700 (HVAC Insulation).

PART 3 - EXECUTION

3.1 INSTALLATION OF REFRIGERANT PIPING

A. Furnish and install all interconnecting refrigerant piping as shown and/or required. Piping shall be run in accordance with equipment manufacturer's recommendations. Pipe sizes shall be as recommended by equipment manufacturer. Test all refrigerant piping for leaks with an electronic leak detector. Seal and flash all roof and wall penetrations. Provide plastic pipe shields between pipe and hanger. Pitch suction piping down in direction of flow.

B. Install refrigerant piping and refrigerant-containing components in accordance with ASHRAE Standard 15 and ASME B31.5
   1. Install piping as short as possible, with a minimum number of joints, elbows, and fittings.
   2. Install piping with adequate clearance between pipe and adjacent walls and hangers to allow for service and inspection. Space piping, including insulation, to provide 1 inch minimum clearance between adjacent piping or other surface. Use pipe sleeves through walls, floors, and ceilings, sized to permit installation of pipes with full thickness insulation.
   3. Locate and orient valves to permit proper operation and access for maintenance of packing, seat and disc. Generally, locate valve stems in overhead piping in horizontal position. Provide a union adjacent to one end of all threaded end valves. Control valves usually require reducers to connect to pipe sizes shown on the drawing.
   4. Use copper tubing in protective conduit when installed below ground.
   5. Install hangers and supports per ASME B31.5 and the refrigerant piping manufacturer's recommendations.

C. Joint Construction
   1. Brazed Joints: Comply with AWS Brazing Handbook and with filler materials complying with AWS A5.8/A5.8M.
   2. Use Type BcuP copper-phosphorus alloy for joining copper socket fittings with copper tubing.
   3. Use Type BAg cadmium-free silver alloy for joining copper with bronze or steel.
   4. Swab fittings and valves with manufacturer's recommended cleaning fluid to remove oil and other compounds prior to installation.
   5. Pass nitrogen gas through the copper piping to prevent oxidation as each joint is brazed. Cap the system with a reusable plug after each brazing operation to retain the nitrogen and prevent entrance of air and moisture.

D. Protect refrigerant system during construction against entrance of foreign matter, dirt, and moisture; having open ends of piping and connections to compressors, condensers, evaporators and other equipment tightly capped until assembly.

E. Pipe refrigerant relief valve discharge to outdoors for systems containing more than 100 lbs of refrigerant.

3.2 REFRIGERANT SYSTEM PRESSURE TESTING, EVACUATION, AND CHARGING

A. Refrigerant system pressure testing, evacuation, and charging procedures shall be performed in the presence of the Owner's representative and/or the Engineer after the refrigerant piping system installation is complete.

B. Prior to evacuation and charging, the refrigerant system shall be pressure tested with nitrogen per the equipment manufacturer’s written recommendations for test pressure(s). Pressure testing shall be conducted when the ambient temperature is relatively stable and shall hold for a minimum of 4 hours without a drop in pressure.

C. Utilize properly sized vacuum pump(s) for refrigerant system evacuation. The refrigerant system compressor shall not be utilized to evacuate the system, nor operated at any time prior to completing the specified triple evacuation procedure. Conduct evacuation and charging procedures at ambient temperatures of 60°F or above whenever practical. If ambient temperatures are consistently below 60°F, contact the Owner and/or the Engineer immediately for approval to proceed or for alternative direction.

D. The first evacuation shall be to 1,000 microns, holding at 1,000 microns for a minimum of two hours. Break the vacuum with either nitrogen or refrigerant.

E. The second evacuation shall be to 750 microns, holding at 750 microns for a minimum of two hours. Break the vacuum with either nitrogen or refrigerant.

F. The third evacuation shall be to 500 microns, holding at 500 microns for a minimum of two hours. Break the vacuum with either nitrogen or refrigerant.

G. After testing, fully charge each system with refrigerant and then conduct a leak test of the entire system with an electronic leak detector.

3.3 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like, and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 31 00 - HVAC DUCTWORK

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

1.2 WORK INCLUDED

A. Types of ductwork specified in this section include the following:

Sheet Metal Ductwork
Flexible Ductwork
Internally Lined Ductwork
Externally Insulated Ductwork

1.3 QUALITY ASSURANCE

A. Installer: A firm with at least three years of successful installation experience on projects similar to that required for this work.

B. SMACNA Compliance: Comply with applicable portions of Sheet Metal and Air Conditioning Contractor's National Association (SMACNA) recommendations for all work in this section.

C. ASHRAE Standards: Comply with applicable portions of American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) recommendations for all work in this section.

D. NFPA Standards: Comply with applicable portions of ANSI/NFPA Standard 90A (Standard for the Installation of Air Conditioning and Ventilating Systems) and ANSI/NFPA 90B (Standard for the Installation of Warm Air Heating and Air Conditioning Systems) for all work in this section.

E. NAIMA Standards: Comply with all applicable portions of the North American Insulation Manufacturers Association (NAIMA) standards for all related work in this section.

1.4 SUBMITTALS

A. Product Data: Submit manufacturer's specifications on manufactured products and factory fabricated ductwork used for the work of this section.

B. As-Built Drawings: At project closeout, submit as-built drawings of installed ductwork, duct accessories, outlets, and inlets.

PART 2 - PRODUCTS

2.1 GENERAL

A. Fabricate all ductwork using a commercial grade of galvanized steel complying with the SMACNA HVAC Duct Construction Standards (latest edition) for the specified duct pressure class.

B. Fabricate ductwork with all accessories installed during fabrication to the greatest extent possible. Refer to Specification Section 233110 (HVAC Ductwork Accessories) for accessory requirements.

C. See Specification Section 230700 (HVAC Systems Insulation) for additional related requirements.

D. All ductwork shall be constructed and sealed in accordance with the requirements of the Sheet Metal and Air Conditioning Contractor's National Association (SMACNA) unless indicated otherwise herein.

E. Construct and seal all ductwork in accordance with the pressure related to the equipment or system to which it is connected unless indicated otherwise herein. See Section 3.1 of this specification for additional requirements and clarification.

F. Ductwork upstream of terminal units shall be 4" w.c. pressure class and ductwork downstream of terminal units shall be 2" w.c. pressure class.

G. Wherever ductwork is to be exposed to view in occupied spaces, provide materials which are free from visual imperfections including pitting, seam marks, roller marks, oil canning, stains and discolorations, and other imperfections, including those which would impair painting.

H. Wherever ductwork is to be exposed to view in occupied spaces and is indicated to be painted, that ductwork shall be fabricated using a commercial grade of phosphatized, galvannealed, or bonderized sheet metal that is specifically formulated for painting.

I. Duct fittings shall be constructed to match the adjoining ductwork and to comply with all duct requirements applicable to fittings. See 'Typical Branch Ducts' details on the drawings for acceptable fitting types.

J. Turning Vanes in Rectangular Duct Elbows: Turning vanes shall be provided in all rectangular duct elbows unless indicated otherwise on the drawings, such as in return air transfer ducts, where turning vanes shall not be installed. All turning vanes shall be SMACNA 'Large' (R=4.5"/SP=3.25"). Turning vanes in medium pressure ducts (3.0" w.c. or greater) shall be double thickness. Turning vanes in low pressure ducts (2.0" w.c. or less) with duct widths 30 inches and smaller shall be single thickness. Turning vanes in low pressure ducts (2.0" w.c. or less) with duct widths 32 inches and larger shall be double thickness.

K. Except as otherwise indicated, or where a reaction between dissimilar metals might occur, provide hot-dipped galvanized steel fasteners, anchors, rods, straps, trim, and angles for support of all ductwork. Utilize Unistrut channel supports and hangers as appropriate for larger duct sizes. Penetrating ductwork with screws shall be avoided to the greatest extent possible. Wherever screws are required to penetrate ductwork the penetrations shall be sealed air and water tight.

2.2 TWO INCH PRESSURE CLASS DUCTWORK

A. Rectangular ductwork shall be fabricated using a commercial grade of galvanized steel complying with the SMACNA HVAC Duct Construction Standards (latest edition) for the specified duct pressure class. Ductwork and fitting gauges shall be in accordance with Chapter 2 of the SMACNA HVAC Duct Construction Standards (latest edition).

B. Round ductwork shall be spiral lock seam round and/or oval duct and fittings.

2.3 ROUND DUCTWORK

A. Round Ductwork: Provide spiral lock seam prefabricated duct, constructed and sealed for 4 inch pressure class. The requirement for spiral lock seam round ducts also applies to 2 inch pressure class round ductwork. Longitudinal seam round ductwork is not acceptable.
Available Manufacturers: Subject to compliance with requirements, manufacturers offering factory fabricated ductwork which may be incorporated in the work include the following, or approved equal:

Manufacturer
McGill Airflow Uni-Seal
Semco
OmniDuct
Air Handling Systems

B. Spiral lock seam prefabricated factory-built round and oval duct and fittings shall be used wherever possible. Shop fabricated ducts shall be used only where rectangular shaped ducts are shown on the drawings or where transitions and special fittings cannot be prefabricated by the factory.

C. Optional Shop Fabricated Ductwork and Fittings: As an alternative to factory fabricated ductwork the Contractor may shop fabricate the spiral seam ductwork provided that certification is submitted and approved indicating that the shop fabricated ductwork and fittings are equal to that specified for factory fabricated ductwork and fittings.

D. Shop-fabricate ductwork in 4, 8, 10, or 12 foot lengths, unless otherwise indicated or required, to complete duct runs. Pre-assemble ductwork in the shop to the greatest extent possible, so as to minimize field assembly of systems. Disassemble systems only to the extent necessary for shipping and handling. Match and mark duct sections for reassembly and for a coordinated installation.

E. Round Fittings: The following round duct fittings shall be used, in accordance with what is depicted on the drawings.

1. All round fittings shall be full bodied type.
2. Round elbows shall be constructed with a 1.5 radius to diameter (R/D) ratio.
3. Round elbows shall be segmented/gored type, constructed in accordance with the current SMACNA Duct Construction Standards. Adjustable elbows are not acceptable.
4. Low loss conical tees, conical laterals, reducing tees, and 90° crosses.
5. Reducers and increasers shall be constructed for a maximum angle of 30 degrees.
6. Spin-in and/or tap-type fittings that require field cuts into the ductwork are not acceptable.
7. No exceptions will be allowed to the listed fitting requirements.

F. Concealed Round Ductwork: Construct of galvanized sheet steel complying with ANSI/ASTM A653, in conformance with the listed manufacturing method, and in the listed minimum duct and fitting gauge.

Diameter	Minimum Duct Gauge	Minimum Fitting Gauge	Manufacturing Method
3" to 14"	28	28	Spiral Lockseam
16" to 24"	26	26	Spiral Lockseam
26" to 42"	24	24	Spiral Lockseam
44" to 60"	22	22	Spiral Lockseam
62" to 96"	20	20	Spiral Lockseam

G. Exposed Round Ductwork: Construct of galvanized sheet steel complying with ANSI/ASTM A653, in conformance with the listed manufacturing method, and in the listed minimum gauge. Note that exposed round ductwork is required to be heavier gauge than concealed round ductwork so that potential damage or denting is less likely.

Diameter	Minimum Duct Gauge	Minimum Fitting Gauge	Manufacturing Method
3" to 14"	26	26	Spiral Lockseam
16" to 24"	24	24	Spiral Lockseam
26" to 42"	22	22	Spiral Lockseam
44" to 60"	20	20	Spiral Lockseam
62" to 96"	18	18	Spiral Lockseam

H. Identification of Round Ductwork and Fittings: To allow for field verification of the appropriate gauge material, round duct and fitting factory labels shall be visible from the floor such that they can be observed prior to insulating.

2.4 HANGERS AND SUPPORTS FOR DUCTWORK

A. See Section 230530 (Hangers and Supports for HVAC Systems)

2.5 SEISMIC BRACING FOR DUCTWORK

A. See Section 230540 (Seismic Bracing for HVAC Systems)

2.6 DUCT ACCESS DOORS

A. See Specification Section 233110 (HVAC Ductwork Accessories).

2.7 DUCTWORK INSULATION

A. All 2 inch pressure class rectangular and round supply, return, and outside air ductwork shall be externally insulated unless specifically indicated otherwise in these specifications or on the drawings. See Specification Section 230700 (HVAC Insulation) for associated requirements.

B. Internal Duct Liner Insulation (When Specified Below and/or Indicated on the Drawings)

1. Provide internal duct liner for the following, unless indicated otherwise on the drawings:
   a. The first 4 feet of rectangular ductwork downstream of each terminal unit.
   b. Rectangular transfer air ducts.
   c. Rectangular ductwork elsewhere as noted on the drawings.
2. Internal duct liner shall be 1-1/2” thick Johns Manville Linacoustic R-300 Duct Liner, or approved equal, with an insulating value of R-6.3 and a 25/50 flame and smoke spread rating in accordance with ASTM E84.
3. Cut and adhere internal duct liner and seal edges in strict accordance with the duct liner manufacturer’s written application instructions.
4. Additionally secure duct liner with weld pins or with Duro-Dyne PBH Dynastick Fasteners adhered with Duro-Dyne PBACZVOC Dynastick Adhesive. Faster spacing shall be in accordance with the insulation manufacturer’s written instructions.
5. Adjust duct sizes to accommodate liner thickness to provide the net internal duct dimensions shown on the drawings.

2.8 DUCTWORK MATERIALS

A. Provide miscellaneous materials and products of types and sizes indicated, unless otherwise indicated. Provide per the requirements listed in the latest SMACNA manuals, including proper connection of ductwork and equipment.

B. Duct Joints: Join and seal prefabricated, factory built ducts, fittings, and couplings in strict accordance with duct manufacturer's instructions. Install duct sealers, pop rivets, or sheet metal screws, canvas, and lagging adhesive on each joint. Duct sealer shall be fire retardant. Sheet metal screws for joints shall be minimum #10 size galvanized.

2.9 SEALANTS

A. Duct sealant shall be water-based, non-fibrated, and fire resistive with a UL 181B listing for use on low, medium, and high pressure ductwork. Sealant VOC levels shall also meet all federal, state, and local requirements and be classified with mildew resistance per ASTM G21 with 0 growth rating.

B. Sealant shall be rated for up to 10” w.c. and shall be installed in strict accordance with the manufacturer’s written instructions. Pressure sensitive tapes are not acceptable.

C. Subject to compliance with requirements, manufacturers offering sealants which may be incorporated in the work include the following:

Design Polymerics DP-1010
Hardcast Iron-Grip 601
Foster 32-19
Childers CP-146

2.10 FLEXIBLE DUCTS

A. Flexible ducts may be used in concealed areas where detailed and as specified.

B. Flexible ducts shall consist of an exterior reinforced laminated vapor barrier, 2 inch thick fiberglass insulation (R-6), encapsulated spring steel wire helix, and impervious, smooth, non-perforated interior vinyl liner. Each individual length of flexible duct shall include factory fabricated steel connection collars. Flexible ducts shall be UL approved and tested and shall meet Class 1 requirements of NFPA 90A.

C. Flexible ducts from rigid runouts to diffusers and registers shall be Thermaflex M-KE, or approved equal, with a maximum length of 5 feet.

D. Comply with all applicable portions of the Air Duct Council Flexible Duct Performance and Installation Standards.

PART 3 - EXECUTION

3.1 INSTALLATION OF DUCTWORK

A. Assemble and install ductwork to achieve air tight and noiseless (no objectionable noise) systems capable of performing each indicated service.

B. Install each run with minimum of joints. Align ductwork accurately at connections within 1/8 inch misalignment tolerance and with internal surfaces smooth. Support ducts rigidly with suitable ties, braces, hangers, and anchors of type which will hold ducts true to shape and to prevent buckling.

C. Install concrete inserts for support of ductwork in coordination with formwork as required to avoid delays in work.

D. Where ducts pass through interior partitions and exterior walls, conceal space between construction opening and duct or duct-plus-insulation with sheet metal flanges of same gauge as duct. Overlap opening on four sides by at least 1-1/2 inches.

E. Support ductwork and piping in a manner complying with Section 230530 (Hangers and Supports for HVAC Piping and Equipment). Where special hanging of ductwork or piping is detailed or shown on drawings, the drawings shall be followed.

F. Duct hangers used in areas where a specialty architectural ceiling or floor occurs shall be compatible for use with that system. See architectural and structural drawings for locations.

G. Seal all ductwork to the seal class required in the following table, and using the methods prescribed in the SMACNA HVAC Air Duct Leakage Test Manual, latest edition.

Duct Class	Up to 2” w.c.	3” w.c.	4” thru 10” w.c. or exposed to weather
Seal Class	C	B	A
Sealing	Transverse Joints Only	Transverse Joints and Seams	Joints, Seams, and all Applicable Wall Penetrations
Leakage Class			
Rectangular Metal	16	8	4
Round Metal	8	4	2

1. Sealant shall be applied 3 inches wide and at 32 mil wet film thickness.

2. For ducts greater than 2” pressure class, or exposed to weather, a first layer of sealant shall be applied to an 18 mil thickness, with scrim applied over the sealant, and then another 18 mil thickness of sealant shall be applied over the scrim.

3.2 INSTALLATION OF FLEXIBLE DUCTWORK

A. Provide supports at or near the mid-length point using 2 inch wide 28 gauge steel hanger collars attached to the structure with an approved duct hanger. Installation shall eliminate sharp radius turns, offsets, or kinks.

B. Bends in flexible ductwork shall be kept to a minimum. The minimum bend radius shall be 1.5 times the duct diameter with no bends greater than 45 degrees. This specifications and any applicable drawings or details shall be strictly adhered to.

C. Each length of flexible duct shall be provided with steel connection collars.

D. Make connections to rigid duct and equipment with draw bands and sealer, and then apply duct tape over outside of sheath.

3.3 CLEANING AND PROTECTION OF DUCTWORK

A. Clean ductwork internally, unit by unit as it is installed, of any dust and debris. Clean external surfaces of foreign substances which might cause corrosive deterioration of metal or where ductwork is to be painted.

B. Strip protective paper from stainless steel ductwork surfaces, and repair finish wherever it has been damaged.

C. Temporary Closure: At ends of ducts which are not connected to equipment or air distribution devices at the time of ductwork installation, provide temporary closure using polyethylene film or other covering which will prevent entrance of dust and debris until the time that connections are to be completed.

3.4 CLEANING EXISTING DUCTWORK

A. Clean all existing HVAC ductwork systems in compliance with NADCA ACR standards, most recent addition. Contractor to submit inspection report to the Engineer and Owner for review before beginning cleaning. The inspection report shall include the entire scope of work. Contractor to proceed based on direction from the Engineer and/or Owner. If duct cleaning is performed, submit a copy of the results to the engineer and owner and include a copy in the close-out documents at the project outset.

3.5 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, and tools, and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 31 10 - HVAC DUCTWORK ACCESSORIES

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

1.2 WORK INCLUDED

A. Types of ductwork accessories specified in this section include volume dampers, control dampers, fire-smoke dampers, turning vanes, duct hardware, duct access doors, flexible connections, and backdraft dampers.

1.3 QUALITY ASSURANCE

A. SMACNA Compliance: Comply with applicable portions of Sheet Metal and Air Conditioning Contractor's National Association (SMACNA) HVAC Duct Construction Standards (Metal and Flexible) latest edition, for all work in this section.

B. ASHRAE Standards: Comply with American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) recommendations, latest edition, for all work in this section.

C. NFPA Compliance: Comply with ANSI/NFPA 90A (Standard for the Installation of Air Conditioning and Ventilating Systems) and ANSI/NFPA 90B (Standard for the Installation of Warm Air Heating and Air Conditioning Systems).

D. Compliance: Construct, test, install and label fire dampers and fire doors in accordance with Underwriters Laboratories (UL) Standard 555 (Fire Dampers and Ceiling Dampers).

E. Dampers shall be warranted against manufacturing defects for a period of 5 years.

F. Dampers shall be tested, rated and labeled in accordance with the latest requirements of UL 555 (Fire Dampers) and UL 555S (Smoke Dampers).

G. Damper pressure drop ratings shall be based on tests and procedures performed in accordance with AMCA 500.

H. Damper pressure drop ratings shall be based on tests and procedures performed in accordance with AMCA 500 and certified in accordance with AMCA 500D.

1.4 REFERENCES

AMCA 500D Laboratory Test Methods for Testing Dampers for Ratings

AMCA 511	Certified Ratings Program for Air Control Devices
IBC	International Building Code
NFPA 80	Fire Doors and Other Opening Protectives
NFPA 90A	Standard for the Installation of Air Conditioning and Ventilating Systems
NFPA 90B	Standard for the Installation of Warm Air Heating and Air Conditioning Systems
NFPA 92A	Smoke Control Systems
NFPA 101	Life Safety Code
NFPA 105	Standard for the Installation of Smoke Door Assemblies
UL 555	Standard for Safety; Fire Dampers
UL 555S	Standard for Safety; Smoke Dampers

1.5 SUBMITTALS

A. Product Data: Submit manufacturer's product data for each type of ductwork accessory, including dimensions, capacities, and materials of construction, and installation instructions.

B. Fire-Smoke Dampers: Submit complete installation instructions for all types of fire damper to be used on this project, as part of main submittal.

PART 2 - PRODUCTS

2.1 TURNING VANES

A. Fabricated Turning Vanes: Provide fabricated turning vanes and vane runners, constructed in accordance with SMACNA HVAC Duct Construction Standards, latest edition.

B. Turning Vanes in Rectangular Duct Elbows: Turning vanes shall be provided in all rectangular duct elbows unless indicated otherwise on the drawings, such as in return air transfer ducts, where turning vanes shall not be installed. All turning vanes shall be SMACNA 'Large' (R=4.5"/SP=3.25"). Turning vanes in medium pressure ducts (3.0" w.c. or greater) shall be double thickness. Turning vanes in low pressure ducts (2.0" w.c. or less) with duct widths 30 inches and smaller shall be single thickness. Turning vanes in low pressure ducts (2.0" w.c. or less) with duct widths 32 inches and larger shall be double thickness.

C. Available Manufacturers: Subject to compliance with requirements, manufacturers offering turning vanes which may be incorporated in the work include the following, or approved equal:

Anemostat
Airsan Corporation

2.2 DUCT HARDWARE

A. Provide duct hardware manufactured by one manufacturer for all items on project for the following:

1. Test Holes: Provide in ductwork at fan inlet and outlet and elsewhere as required. Plastic test plugs may only be used on low pressure ductwork (2" w.c. or less). Test holes installed in medium pressure ductwork (above 2" w.c.) and at outdoor equipment shall be covered with Ventlok Model 699 covers, or approved equal.
2. Quadrant Locks: Provide for each damper quadrant lock device on one end of shaft and end-bearing plate on other end. Provide extended quadrant locks and extended bearing plates for externally insulated ductwork.

B. Available Manufacturers: Subject to compliance with requirements, manufacturers offering duct hardware which may be incorporated in the work include the following, or approved equal:

Ventfabrics
Ventlok by Ventfabrics

2.3 DUCT ACCESS DOORS

A. Provide airtight access doors in ducts and plenums for cleaning and repairs of fire dampers, control devices, etc. and where shown on the drawings. Access door size shall be duct width by duct height for all ducts under 24 inches. Minimum access door size shall be 8 inches by 8 inches. Ducts over 24 inches in diameter shall have 24 inch by 18 inch access doors.

B. Access doors shall be rated for the associated duct pressure (positive or negative).

C. Access doors in supply air and return air ducts shall be insulated as required to provide a minimum R-6.0 rating. Insulation shall be 25/50 rated in accordance with ASTM E84. Access doors in supply air and return air ducts shall be Ductmate Model FD, or approved equal.

D. Access doors in low pressure ductwork (3.0” w.c. and below) shall be hinged with cam latches, and a perimeter gasket.

E. Access doors in medium pressure ductwork (4.0” w.c. and above) shall be constructed with cam latches and a perimeter gasket.

F. Access doors in stainless steel ductwork shall be constructed of stainless steel.

G. Access doors in grease exhaust ducts shall be UL listed, shall be Ductmate Ultimate, or approved equal.

H. Access doors shall be permanently identified on the exterior by a permanent label with letters not less than 1/2 inch in height reading ‘Fire-Smoke Damper’ or as otherwise appropriate.

I. Available Manufacturers: Subject to compliance with requirements, manufacturers offering duct access doors which may be incorporated in the work include the following, or approved equal:

Ductmate
Best Access Doors
United McGill

2.4 FLEXIBLE CONNECTIONS

A. Furnish and install flexible connections at following locations:

At supply connection on all motorized heating and cooling equipment.
At return connection on all motorized heating and cooling equipment.
At duct connection on all exhaust fans.
Elsewhere as shown on the drawings.

B. Flexible connections are not required for curb-mounted or roof-mounted exhaust fans.

C. Flexible duct connections shall be preassembled flexible connectors constructed of coated glass fabric applied in accordance with manufacturer's recommendations. Width of flexible connections shall be sufficient to allow minimum of 2 inches of free space between two metal collars to be connected. Install sheet metal band completely around duct or fan outlet, at end of flexible connection. Fasten with metal screws through band and coated glass fabric. Space screws approximately 3 inches apart. Coated glass fabric shall be equal to Ventfabrics Ventglas with neoprene coating for use inside building and Ventlon with hypalon coating when exposed to weather.

D. Available Manufacturers: Subject to compliance with requirements, manufacturers offering flexible connections which may be incorporated in the work include the following:

Ventfabrics
Thermaflex

2.5 MANUAL VOLUME DAMPERS, CONTROL DAMPERS, AND BACKDRAFT DAMPERS

A. Manual Dampers: Provide manual volume dampers in all locations shown on the drawings. Dampers shall be single blade type or multi-blade type, constructed in accordance with the SMACNA HVAC Duct Construction Standards, latest edition. Damper blades shall not exceed 6 inch width, except that 8 inch wide dampers may be used in 8 inch wide ducts.

B. Concealed Damper Actuators: Where dampers are installed above non-accessible ceilings and are not served by access doors, provide extension cables and concealed ceiling mounted damper regulators. Damper regulator shall be Young Regulator Model 270-896, or approved equal.

C. Remote Powered Balancing Dampers: Where indicated on the drawings, provide remote powered balancing dampers complete with motorized damper, connecting cable, wall plate with ports, and battery powered remote control device. Dampers shall be Greenheck Model RBDR-50, Pottorff Model RD-10R, or approved equal.

D. Control Dampers: Provide dampers with low leakage opposed blades, frame and blades constructed of 16 gauge galvanized steel, suitable for electric actuators.

E. Backdraft Dampers: Provide dampers with parallel blades, constructed of 16 gauge aluminum; provide 1/2 inch diameter ball bearings, 1/2 inch diameter steel axles spaced on 9 inch centers. Construct frame of 2" x 1/2" x 1/8" thick steel channel for face areas 25 sf and under; and 4" x 1-1/4" x 16 gauge channel for face areas over 25 sf. Provide galvanized steel finish on frame with aluminum touch-up.

F. Available Manufacturers: Subject to compliance with requirements, manufacturers offering dampers which may be incorporated in the work include the following, or approved equal:

Greenheck
Ruskin
Air Balance

2.6 DUCT SMOKE DETECTORS

A. Duct smoke detectors shall be installed at the locations shown on the drawings, as listed in the equipment schedules, and as described herein.

B. Duct smoke detectors shall be furnished by Division 26. Installation of duct smoke detectors and wiring between duct smoke detectors and the associated mechanical equipment shall be by Division 23. Electrical power to duct smoke detectors and wiring to the fire alarm control panel shall be by Division 26.

C. It is the mechanical contractor's responsibility to ensure that their bid includes a complete installation that is coordinated with the duct smoke detectors, equipment, and all applicable code requirements.

D. Duct smoke detectors shall be installed in conformance with Uniform Mechanical Code Section 608. Equipment that has a scheduled airflow in excess of 2,000 cfm shall have a duct smoke detector installed in both the supply air and the return air.

E. Equipment that has a scheduled airflow in excess of 15,000 cfm and serves multiple floors of a building shall have duct smoke detectors installed in the return air duct where the return air exits each floor of the building (prior to the main return air riser) in addition to the supply air duct smoke detector(s) specified in this section.

F. In cases where there are no Division 26 plans and specifications, duct smoke detectors shall be furnished and installed by Division 23. Such duct smoke detectors shall be manufactured by Edwards, Notifier, or approved equal. On projects where duct smoke detectors will be connected to an existing fire alarm system, the new duct detectors shall match the existing system manufacturer's devices. Duct smoke detectors shall include dual auxiliary contacts for interface with the fire alarm system and the direct digital control system.

PART 3 - EXECUTION

3.1 INSTALLATION OF DUCT ACCESSORIES

A. Install duct accessories in accordance with the manufacturer's installation instructions, with applicable portions of details of construction as shown in the SMACNA Standards, and in accordance with recognized industry practices as necessary to ensure that the products serve the intended function.

B. Install turning vanes in square and/or rectangular 90 degree elbows in supply and exhaust air systems and elsewhere as indicated.

C. Install access doors to open against system air pressure, with latches operable from either side, except on the outside only where the duct is too small for a person to enter.

D. Coordinate with other work as necessary to interface installation of duct accessories properly with other work.

E. Field Quality Control: Operate installed duct accessories to demonstrate compliance with requirements. Test for air leakage while system is operating. Repair or replace faulty accessories as required to obtain proper operation and leak-proof performance.

3.2 CARE AND CLEANING

A. Repair or replace broken, damaged, or otherwise defective parts, materials, and work. Leave entire work in condition satisfactory to the Architect/Engineer. At completion, carefully clean and adjust equipment, fixtures, and trim installed as part of this work. Leave systems and equipment in satisfactory operating condition.

3.3 OPERATION TEST

A. Test each piece of equipment to show that it will operate in accordance with the indicated requirements.

3.4 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like, and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 34 00 - HVAC FANS AND HOODS

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

1.2 WORK INCLUDED

A. Types of fans, hoods, and curbs specified in this section include the following:
In-Line Centrifugal Fans
Upblast Exhaust Fans
Base Mounted Centrifugal Exhaust Fans

1.3 SUBMITTALS

A. Product Data: Submit manufacturer's technical product data and installation instructions for each type of material listed in this section.

B. Operation and Maintenance Data: Submit operation and maintenance data and replacement material lists for each type of material listed in this section. Include this data and product data in the operation and maintenance manual.

PART 2 - PRODUCTS

2.1 IN-LINE CENTRIFUGAL FANS

A. Provide direct drive in-line fans of sizes and arrangement as indicated, and of capacities and having accessories as scheduled. Fans shall be Greenheck SQ, or approved equal.

B. Ratings: Test and rate fans in accordance with ASHRAE Standards. Provide with AMCA Certified Ratings Seal for both air flow and sound.

C. Fan Units: Provide factory-assembled and tested fan units consisting of housing, wheel, fan shaft, bearings, and fan drive. Clean, condition, and prime paint sheet metal parts prior to final assembly. Apply final coat of enamel to exterior surfaces after assembly.

D. Wheels: Balance wheels statically and dynamically near operating speed.

E. Backdraft Damper: Provide a factory-furnished, field-installed backdraft damper at each in-line exhaust fan.

F. Bearings: Provide sealed, pillow block type bearings, selected for a minimum average life of 200,000 hours.

G. Motors: Provide open drip-proof motors with ball or sleeve bearings. Provide split phase or capacitor start motors for fractional horsepower, with resilient base. Provide induction motors for integral horsepower, with rigid base. Provide non-fusible type disconnect switch for all 120 volt fans. Where scheduled, provide Greenheck Vari-Green EC motor with factory furnished speed control.

H. Drives: Where scheduled provide V-belt drives selected for a 1.5 service factor. Provide adjustable pitch sheave selected for midpoint at design conditions.

I. Available Manufacturers: Subject to compliance with requirements, manufacturers offering in-line centrifugal fans which may be incorporated in the work include the following, or approved equal:

Greenheck
PennBarry
Cook

2.2 BASE MOUNTED CENTRIFUGAL EXHAUST FANS (UTILITY SETS)

A. Provide centrifugal exhaust fans, of type, size, arrangement, and capacity as scheduled on the drawings, and as specified herein. Fans shall be Greenheck Model USF, or approved equal.

B. Ratings: Test and rate fans in accordance with ASHRAE Standards. Provide with AMCA Certified Ratings Seal for both airflow and sound.

C. Type: Direct drive or belt drive, as scheduled on the drawings. Provide capacitor-start, induction-run type motor for belt drive fans. For direct drive fans, provide an EC motor with a factory furnished speed control.

D. Provide factory-installed restrained spring mount vibration isolators where shown on drawings, access door, backdraft damper, belt guard, extended lubrication lines, outlet guard, and motor cover.

E. Electrical: Provide factory-wired non-fusible type disconnect switch at motor in fan housing. Provide thermal overload protection in fan motor. Provide conduit chase within unit for electrical connection.

F. Available Manufacturers: Subject to compliance with requirements, manufacturers offering kitchen exhaust fans which may be incorporated in the work include the following, or approved equal:
Greenheck
PennBarry
Cook

PART 3 - EXECUTION

3.1 GENERAL

A. Install fans and ventilators where indicated, in accordance with equipment manufacturer's installation instructions, and with recognized industry practices, to ensure that equipment complies with requirements and serves intended purposes.

B. Provide motors so that they cannot be overloaded above nameplate rating throughout the full speed range of the adjustable pitch driving sheave.

C. Fan wheels shall be balanced statically and dynamically near operating speed.

D. Provide drives and guards conforming to the requirements hereinbefore specified.

E. Fan construction, speed, noise level, tip speeds, outlet velocities, and efficiencies will be taken into consideration in assessment of all fans that are submitted.

3.2 ELECTRICAL CONNECTIONS

A. Ensure air distribution equipment is wired properly, with rotation in direction indicated and intended for proper performance.

3.3 CARE AND CLEANING

A. Repair or replace broken, damaged or otherwise defective parts, materials, and work. Leave entire work in condition satisfactory to Owner’s representative. At completion, carefully clean and adjust equipment and trim installed as part of this work. Leave systems and equipment in a satisfactory operating condition.

3.4 OPERATION TEST

A. Test each piece of equipment to show that it will operate in accordance with the indicated requirements.

3.5 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like and leave the premises clean, neat and orderly.

END OF SECTION

SECTION 23 80 20 - INDOOR SEMI-CUSTOM AIR HANDLING UNITS

PART 1 - GENERAL

1.1 CONDITONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

1.2 REFERENCES

A. AMCA Standard 99: Standards Handbook

B. AMCA /ANSI Standard 204: Balance Quality and Vibration Levels for Fans

C. AMCA Standard 210: Laboratory Methods of Testing Fans for Ratings

D. AMCA Standard 300: Reverberant Room Method for Sound Testing of Fans

E. AMCA Standard 500: Test Methods for Louvers, Dampers, and Shutters

F. AHRI Standard 410: Forced Circulation Air Cooling and Air Heating Coils

G. ASHRAE Standard 52: Gravimetric and Dust Spot Procedures for Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter

H. ASHRAE/ANSI Standard 111: Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air Conditioning, and Refrigeration Systems

I. UL Standard 1995: Heating and Cooling Equipment

J. ASTM A-525: Specification for General Requirements for Steel Sheet, Zinc Coated (Galvanized) using the Hot Dip Process

1.3 SUBMITTALS

A. Submit shop drawings and product data in accordance with Division 1.

B. Submittals shall include the following:

1. Dimensioned plan and elevation view drawings, including motor starter and control cabinets, required clearances, and location of all field connections.
2. Summary of all auxiliary utility requirements such as: electricity, water, compressed air, etc. Summary shall indicate quality and quantity of each required utility.
3. Ladder type schematic drawing of the power and ancillary utility field hookup requirements, indicating all items that are furnished.
4. Manufacturer’s performance of each unit. Selection data shall indicate, as a minimum, the following:
    a. Input data used for selection.
    b. Model number of the unit.
    c. Net capacity.
    d. Rated load amp draw.
    e. Noise levels produced by equipment.
    f. Fan curves.
    g. Approximate unit shipping weight.

1.4 OPERATION AND MAINTENANCE DATA

A. Include data on design, inspection and procedures related to preventative maintenance. Operation and maintenance manuals shall be submitted at the time of unit shipment.

1.5 QUALIFICATIONS

A. Manufacturer shall be a company specializing in the design and manufacture of custom commercial HVAC equipment. Manufacturer shall have been in production of custom HVAC equipment for a minimum of 5 years.

B. Each unit shall bear an ETL or UL label under UL Standard 1995 indicating the complete unit is listed as an assembly. ETL or UL listing of individual components, or control panels only, is not acceptable.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, protect and handle products to site under the supervision of the Owner.

1.7 SEQUENCING AND SCHEDULING

A. Coordinate work performed under this section with work performed under the separate installation contract.

1.8 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed, are packaged with protective covering for storage, and identified with labels describing contents.

1. Three sets of spare filters for each unit.

1.9 WARRANTY

A. The complete unit shall be covered by a parts warranty issued by the manufacturer covering the first year of operation. This warranty period shall start upon receipt of start-up forms for the unit or eighteen months after the date of shipment, whichever occurs first.

B. The installing contractor shall provide a material and labor warranty during the first year of unit operation.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Provide custom outdoor air handling units as manufactured by one of the following, or approved equal:

Daikin
Miller Picking
Scott Springfield

2.2 GENERAL

A. Furnish and install where shown in the air handling unit schedule and on the plans, mechanical frame style air handling units specifically designed for an indoor application with construction features as specified herein. The units shall be provided and installed in strict accordance with the specifications. All units shall be complete with all components and accessories as specified. Any exceptions must be clearly defined. The contractor shall be responsible for any additional expenses that may occur due to any exception made.

2.3 FACTORY TESTING AND QUALITY CONTROL

A. Standard Factory Testing: The fans shall be factory run tested to ensure structural integrity and proper RPM. All electrical circuits shall be tested to ensure correct operation before shipment of unit. Units shall pass quality control and be thoroughly cleaned prior to shipment.

2.4 UNIT CONSTRUCTION

A. Configuration: Fabricate as indicated on drawings.

B. Acoustics: The sound power level for each unit at 125 Hz shall not exceed 75 dB. The manufacturer shall provide the necessary sound treatment to meet these levels as required.

C. IBC Certification
   1. All components included herein shall be designed, manufactured, independently tested, rated, and certified to meet the seismic compliance standards of the 2018 International Building Code. Components designated for use in systems that are life safety, toxic, high hazard, combustible or flammable shall meet the on line, anchorage and load path requirements for life safety as defined in the IBC and IBC Commentary,
   2. All completed component assemblies shall be clearly labelled for field inspection. Seismic compliance labels shall include the manufacturer's identification, designation of certified models, definitive information describing the product's compliance characteristics, and the Independent Certifying Agency's name and report identification.
   3. In addition to all seismic requirements for IBC certification listed elsewhere in the project specifications, manufacturer's submittals shall include a certificate of compliance from the Independent Certifying Agency clearly indicating that components supplied on this project are included in the component manufacturer's Certificate of Compliance.

D. Unit Casing: Fabricate unit with 16 gauge channel posts and panels secured with mechanical fasteners. All panels, access doors, and ship sections shall be sealed with permanently applied bulb-type gasket material. Gasketing shipped loose is not acceptable.
   1. Panels and access doors shall be constructed as a 2 inch nominal thickness thermally broken double wall assembly, injected with foam insulation for a minimum R-Value of R-13. The outer panel shall be constructed of G90 galvanized steel. The inner liner shall be constructed of G90 galvanized steel .
   2. Panel deflection shall not exceed an L/240 ratio at 125% of the design static pressure, at a maximum positive or negative 8 inches of static pressure. Deflection shall be measured at the midpoint of the panel height.
   3. Panel assembly shall meet UL standard 1995 for fire safety. Panel assembly shall comply with the material requirements of NFPA 90A .
   4. The casing leakage rate shall not exceed .50 cfm per square foot of casing surface area at design static pressures up to a maximum of +5.0" w.c. in positive pressure sections and -6.0" w.c. in negative pressure sections.
   5. Module to module assembly shall be accomplished with an overlapping, full perimeter, internal splice joint, sealed with bulb type gasketing on both mating modules to minimize on site labor and meet indoor air quality standards .
   6. A sound baffle shall be secured to the inner liner and constructed of G60 galvanized perforated steel filled with fiberglass insulation.
   7. A .044" thick aluminum treadplate shall be secured to the floor panel.
   8. The entire unit shall have a 6 inch full perimeter base rail for structural rigidity and condensate trapping. The manufacturer shall submit calculations used to determine the required height of the base rail to allow for adequate drainage.
   9. Access doors shall be flush mounted to cabinetry with minimum of two six inch long stainless steel piano-type hinges, latch, and full size (4 .5" minimum) handle assembly.
   10. Provide an inspection window for the fan section.
   11. Doors shall swing outward for unit sections under negative pressure, and inward for unit sections under positive pressure. Doors limited from swinging inward (such as side access filter sections) on positive pressure sections, shall have a secondary latch to relieve pressure and prevent injury upon access.

12. Construct drain pans from stainless steel with cross breaking and double sloping pitch to the drain connection. Provide drain pans under the cooling coil section. Drain connection centerline shall be a minimum of 3” above the base rail to aid in proper condensate trapping. Drain connections that protrude from the base rail are not acceptable. There shall be a full 2” thickness of insulation under each drain pan.

E. Supply Fans
   1. Provide direct drive airfoil plenum supply fan(s). Fan assemblies including fan, motor, and sheaves shall be dynamically balanced by the manufacturer on all three planes and at all bearing supports. The manufacturer shall ensure that the maximum fan RPM is below the first critical speed.
   2. Fan section shall come equipped with a motor control panel with short circuit protection. Wiring shall be configured to allow for a field installed variable frequency drive (furnished and installed by others).
   3. Motor control panel shall come equipped with a [fused][non-fused] disconnect switch]

F. Electrical
   1. The air handler(s) shall be ETL and ETL-Canada listed by Intertek Testing Services. Units shall conform to bi-national standard ANSI/UL Standard 1995/CSA Standard C22 .2 No . 236.
   2. Wiring Termination: Provide terminal lugs to match branch circuit conductor quantities, sizes, and materials indicated . Enclosed terminal lugs in terminal box sized to NFPA 70 .
   3. Provide marine light and GFI receptacle in each section mounted and wired to a junction box and an on-off switch mounted on the outside of the cabinet.
   4. Fan motors shall be premium efficiency inverter rated to meet EPAct requirements. Electrical characteristics shall be as listed in the schedule on the drawings.
   5. The air handler manufacturer shall provide and mount conduit and wiring from each fan motor terminated at an external non-fused disconnect switch (factory wired). The disconnect switch shall be furnished with a rotary or switch-blade type handle that can be padlocked in the ‘off’ position.
   6. The air handler manufacturer shall provide and mount a Hand-Off-Auto switch for the supply fan(s).
   7. The air handler manufacturer shall provide and mount a 50 VA 24Volt transformer.
   8. The air handler manufacturer shall provide ASHRAE 90.1 Energy Efficiency equation details for individual equipment to assist the Engineer with calculating system compliance.

G. Heating and Cooling Coil Sections
   1. Provide access to coils for service and cleaning.
   2. Enclose coil headers and return bends fully within the unit casing. The unit shall be provided with coil connections that extend a minimum of 5 inches beyond unit casing for ease of installation. Drain and vent connections shall be provided exterior to the unit casing. Coil connections shall be factory sealed with grommets on interior and exterior and gasket sleeve between outer wall and liner where each pipe extends through the unit casing to minimize air leakage and condensation inside the panel assembly.
   3. If not factory packaged, the Contractor shall supply all coil connection grommets and sleeves. Coils shall be removable through side and/or top panels of the unit without the need to remove and disassemble the entire section from the unit.
   4. Identify fin, tube & casing material type and thickness.
   5. Show coil weights (shipping & operating).
   6. State air and fluid flow amounts with its associated pressure drops.
   7. Indicate entering and leaving air and water temperatures. For refrigerant coils, indicate saturated suction temperature (SST).
   8. Certification: Acceptable water coils shall be certified in accordance with AHRI Standard 410 and bear the AHRI label.

9. Headers shall consist of seamless copper tubing to assure compatibility with primary surface. Headers shall have intruded tube holes to provide maximum brazing surface for tube to header joint, strength, and inherent flexibility. Header diameter should vary with fluid flow requirements.
10. Fins shall be aluminum or copper plate construction. Fins shall have full drawn collars to provide a continuous surface cover over the entire tube for maximum heat transfer. Tubes shall be mechanically expanded into the fins to provide a continuous primary to secondary compression bond over the entire finned length for maximum heat transfer rates. Bare copper tubes shall not be visible between fins.
11. Coil tubes shall be 5/8 inch OD seamless copper, .035" nominal tube wall thickness, expanded into fins, and brazed at joints. Soldered U-bends shall be provided to minimize the effects of erosion and premature failure.
12. Coil connections shall be NPT threaded red brass with connection size to be determined by the manufacturer based upon the most efficient coil circuiting. Vent and drain fittings shall be furnished on the connections, exterior to the air handler. Vent connections shall be provided at the highest point to ensure proper venting. Drain connections shall be provided at the lowest point to ensure complete drainage and prevent freezing.
13. Coil casings shall be a formed stainless steel channel frame.
14. Hot Water Coils: 1 and 2 row coils shall be furnished as uncased to allow for thermal movement and shall slide into a pitched track for fluid drainage.

2.5 CONDENSING UNITS

A. Provide condensing units in locations as indicated and with capacities, style, and accessories as scheduled on the drawings.

B. Performance of condensing unit shall be in accordance with ARI Standard 365-94.

C. Condensing unit shall utilize R32 refrigerant.

D. Condensing unit shall include a scroll type compressor.

E. Available Manufacturers: Subject to compliance with requirements, manufacturers offering condensing units which may be incorporated in the work include the following, or approved equal:
Daikin
Carrier
Trane

2.6 REFRIGERANT PIPING

A. See Specification Section 232400 (Refrigerant Piping and Accessories).

PART 3 - EXECUTION

3.1 CARE AND CLEANING

A. Repair or replace broken, damaged, or otherwise defective parts, materials, and work. Leave entire work in condition satisfactory to Owner's representative. At completion, carefully clean and adjust equipment and trim installed as part of this work. Leave systems and equipment in a satisfactory operating condition.

3.2 OPERATION TEST

A. Test each piece of equipment to show that it will operate in accordance with the indicated requirements.

3.3 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 84 10 - BLOWER COIL UNITS

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC Systems) are hereby made a part of this section.

1.2 WORK INCLUDED

A. Types of units specified in this section include the following:

Blower Coil Units (Direct Drive with EC Motors)

B. Units shall be manufactured by Price, Daikin, Enviro-Tec, Trane, or approved equal.

1.3 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed, are packaged with protective covering for storage, and identified with labels describing contents.

1. Two sets of spare filters for each unit.

1.4 QUALITY ASSURANCE

A. ARI Compliance: Coil ratings shall be in conformance with the requirements of ARI Standard 410 (Forced Circulation Air Cooling and Air Heating Coils).

1.5 SUBMITTALS

A. Product Data: Submit manufacturer's technical product data and installation instructions for each type of equipment and material listed in this section.

PART 2 - PRODUCTS

2.1 GENERAL

A. Furnish and install direct drive hydronic blower coil units where indicated on the drawings. Units shall be completely factory assembled, tested, and shipped as one piece.

B. All units shall be capable of meeting or exceeding the scheduled capacities for cooling, heating, and air delivery. Unit dimensions for each model and size shall be considered maximums.

C. All units shall be of draw-thru design with coils, fans, motor(s), and drain pan completely contained within the unit cabinet.

D. Units shall be ETL or cETL listed in compliance with UL/ANSI Standard 1995.

E. All coils shall meet or exceed the scheduled cooling and heating capacity, selected and rated in accordance with AHRI 410.

2.2 CONSTRUCTION

A. All units shall be fabricated of minimum 18 gauge galvanized steel, able to withstand a 125 hour salt spray test per ASTM B-117. Panels shall be die-formed multi-bend construction for optimum strength and rigidity.

B. All exterior panels shall be insulated with 1 inch thick fiberglass insulation rated for a maximum velocity of 3600 fpm. Insulation shall meet all requirements of ASTM C1071 (including C665), UL181 for erosion, and carry a 25/50 rating for flame spread/smoke developed per ASTM E-84.

C. All units shall have a minimum 1” duct collar on both the discharge and return.

D. Required Option: The blower coil unit shall have hinged access panels on the side and bottom. No coil piping, drain piping, or electrical connections shall pass through any access panel.

E. Required Option: Each unit shall be furnished with a one piece heavy gauge stainless steel drain pan with welded corner construction. Drain pan shall be insulated with minimum 1/8” closed cell foam, or with 1” thick, 1.5 lb density fiberglass.

F. Required Option: Each unit shall be provided with a secondary drain connection on the primary condensate drain pan.

G. All units shall be provided with 9/16” diameter hanger rod holes in the top and bottom panels for through-bolt type suspension installation.

2.3 FAN AND MOTOR ASSEMBLY

A. All units shall be furnished with double width, double inlet, forward curved centrifugal blowers statically and dynamically balanced for smooth operation. Blower wheels shall be mounted directly on the motor shaft. Belt driven blowers are not acceptable.

B. Fan motors shall be electronically commutated (ECM type) with thermal overload protection and a constant torque operation. RPM control shall not be acceptable. Motors shall have permanently lubricated ball bearings and shall operate on three phase or single phase power.

C. All motors shall be installed, factory programmed, and wired to the control panel.

D. All motors shall be isolated via belly band or torsion flex mount to the blower housing.

E. All motor wiring is to be terminated in a junction box, external to the unit casing.

F. All motors shall be operated by variable speed local or remote controller.

2.4 COILS

A. All unit coils shall be rated in accordance with AHRI 410. All coils shall be 1/2" OD seamless copper tubes with collared aluminum fins. All tubes shall be mechanically expanded to provide an efficient bond between tube and fin. All water coils shall be provided with a manual air vent fitting to allow for coil venting. Valve core type vent fittings are not acceptable.

B. All chilled water, hot water, and direct expansion coils shall have aluminum fins and 0.016" tube wall thickness.

C. All coils shall be hydrostatically tested with air under water at 450 psi minimum pressure and rated for a maximum of 450 psi working pressure at 200°F.

D. All steam coils shall have 0.025” tube wall thickness and shall be rated for 15 psi maximum operating pressure.

2.5 ELECTRICAL PROVISIONS

A. The unit fan motor shall be completely factory wired to an external electrical enclosure. Each unit shall include fan control package with 24 volt control voltage. Each unit shall include a motor control board, motor circuit fusing, control circuit transformer and terminal strip for connection of field wiring.

B. Motor control shall be provided by a single speed or proportional speed controller mounted on the exterior surface of the control box. Opening the control box to adjust the fan speed shall not be required.

C. Calibrated airflow curves shall be provided near the control box to aid in testing and balancing.

D. A main incoming power non-fused disconnect switch with lock-out-tag-out ready feature shall be factory furnished and wired by the unit manufacturer for single point power connection.

2.6 FILTER RACK ASSEMBLY

A. Provide a custom filter rack as scheduled on the drawings, with standard size 2” thick filter(s).

PART 3 - EXECUTION

3.1 INSPECTION

A. Examine areas and conditions under which units are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Contractor.

3.2 ELECTRICAL WIRING

A. Install electrical devices furnished by the manufacturer but not specified to be factory mounted. Furnish a copy of the manufacturer's wiring diagram to the electrical contractor.

B. Route electrical power and control wiring in separate conduits.

3.3 CARE AND CLEANING

A. Repair or replace broken, damaged, or otherwise defective parts, materials, and work. Leave entire work in condition satisfactory to Architect. At completion, carefully clean and adjust equipment, fixtures, and trim installed as part of this work. Leave systems and equipment in a satisfactory operating condition.

3.4 OPERATION TEST

A. Test each piece of equipment to show that it will operate in accordance with the indicated requirements.

3.5 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like, and leave the premises clean, neat, and orderly.

END OF SECTION

SECTION 23 89 20 - DUCT MOUNTED HYDRONIC HEATING COILS

PART 1 - GENERAL

1.1 CONDITIONS OF THE CONTRACT

A. Sections 230000 (Heating, Ventilating, and Air Conditioning) and 230500 (Basic Materials and Methods for HVAC) are hereby made a part of this section.

1.2 WORK INCLUDED

A. Types of units specified in this section include the following:
Duct Mounted Hydronic Heating Coils

1.3 SUBMITTALS

A. Product Data: Submit manufacturer's technical product data and installation instructions for each type of equipment listed in this section.

1.4 WARRANTY

A. The manufacturer shall repair or replace any components of the hydronic heating coils that fail in materials or workmanship within the one year warranty period.

PART 2 - PRODUCTS

2.1 DUCT MOUNTED HYDRONIC HEATING COILS

A. Furnish and install hydronic heating coils with sizes and capacities as scheduled on the drawings. Units shall be listed by CSA as certified to CSA-C22.2 No. 236-05 (Heating and Cooling Equipment) and UL Standard. No. 1995 (Heating and Cooling Equipment).

B. Available Manufacturers: Subject to compliance with requirements, manufacturers offering hydronic heating coils which may be incorporated in the work include the following, or approved equal:
Nortek
Greenheck
Modine
Trane
Emergent

2.2 COIL CASING

A. Casings shall be minimum 20 gauge galvanized steel.

2.3 COILS

A. Coils shall be of the extended surface type, utilizing aluminum fins and copper tubes with threaded copper, cast bronze, or schedule 40 steel supply and return connections. Tubes shall be mechanically bonded to the collars of the fins. Fins shall be continuous across the width and depth of the coil and vertically oriented to minimize the collection of dirt and dust.

B. Coils shall be rated in accordance with ARI Standard 410 (Forced-Circulation Air Cooling and Air Heating Coils). Coils shall be rated for operation at steam or hot water pressures and temperatures up to 150 psi and 375°F.

PART 3 - EXECUTION

3.1 INSPECTION

A. Examine areas and conditions under which terminal units are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in a manner acceptable to the Contractor.

3.2 ELECTRICAL WIRING

A. Install electrical devices furnished by manufacturer but not specified to be factory mounted. Furnish copy of manufacturer's wiring diagram to the electrical contractor.

3.3 CARE AND CLEANING

A. Repair or replace broken, damaged, or otherwise defective parts, materials, and work. Leave entire work in condition satisfactory to Architect/Engineer. At completion, carefully clean and adjust equipment, fixtures, and trim installed as part of this work. Leave systems and equipment in a satisfactory operating condition.

3.4 OPERATION TEST

A. Test each piece of equipment to show that it will operate in accordance with the indicated requirements.

3.5 CLEANING UP

A. Upon completion of the Work remove materials, equipment, apparatus, tools, and the like, and leave the premises clean, neat, and orderly.

END OF SECTION